Experimental Psychology and Pedagogy

RUDOLF PINTNER

EXPERIMENTAL PSYCHOLOGY AND PEDAGOGY

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For Teachers, Normal Colleges, and Universities

BY

R. SCHULZE

TRANSLATED BY

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TRANSLATOR'S PREFACE

The present volume has found a wide sale in Germany, and the translator trusts it will be of help to students and teachers in Britain and America. It makes no claim to be a complete text-book or manual of experimental psychology. The author emphasises this in his preface. It merely deals with those methods of experimental psychology that are particularly adapted to educational purposes.

The author himself has carried out many experiments, and these he takes as a foundation for his work. Many are not exact, and many are merely tentative, but such work is of value to the beginner, for it shows him what he must expect in his own work, and the suggestions of the author as to where further experiments are required are invaluable.

Most of these experiments were carried out in the Psychological Institute of the Leipsic Teachers' Association, an institute founded and supported by an association of elementary school teachers. This should prove a stimulus to British associations to follow on the same lines. Only by making education a science can teachers hope to raise the status of their profession.

As regards terminology I have followed Judd and Titchener in their translations of terms of the Wundtian psychology.

I am under great obligations to my friend Mr. D. Kennedy Fraser, M.A., B.Sc., who has taken a great deal of trouble in reading the manuscript and verifying the work throughout.

RUDOLF PINTNER.

EDINBURGH, *February* 1912.

PREFACE

The present volume has been written with the intention of introducing the experimental method in psychology and pedagogy to a wider circle of readers. I have, therefore, endeavoured to give a popular presentation of the matter, and thus it follows that only some methods and apparatus can be described. The book lays no claim to completeness in any direction. I have selected what I think necessary for teachers, normal students, and all those interested in the progress of education.

In arranging the matter of such a book, three standpoints might be taken :—according to the apparatus, the methods, or the chief divisions of pure psychology. The first would have laid too much stress upon the purely technical side of our subject. The second might have given rise to the notion that a discussion of the methods of psychology was alone intended. I therefore decided to use the third standpoint, to arrange the matter according to the chief divisions of psychology. In the choice of these divisions, in the arrangement and in the terminology I have followed Wundt.

I have added here and there to the description of the apparatus and methods, some results of modern research. These are only to be considered as examples. I make no claim to have given in every case the most important results. On the contrary I have, as far as possible, used my own results for purposes of elucidation, because I

am most familiar with them and because they are sufficient to exemplify what an experiment may aim at.

The other results I have taken out of the two chief sources for psychology and experimental pedagogy—Wundt's *Grundzüge der physiologischen Psychologie* and Meumann's *Vorlesungen zur Einführung in die experimentelle Pädagogik und ihre psychologischen Grundlagen.* I take it for granted that whoever wishes to conduct experiments for himself will refer to these two works. There he will find all the necessary literature, and for that reason I have thought it unnecessary to overload my book with endless references to the literature of the subject.

I have held it of the greatest importance to provide sufficient illustrations and diagrams. Thanks to the generous help of many authors, publishers, and scientific institutes, I have been enabled to achieve my end. In every case I have noted my obligation. Illustrations, where the original is not indicated, have been prepared by myself specially for this book.

I have to acknowledge my indebtedness to the many ladies and gentlemen who took part in my experiments, and who rendered me valuable assistance in taking the photographs; also to the principals and the teachers, who permitted me to take photos of school-children. And lastly I must thank Messrs. Döring and Schlager for reading and correcting the MS. Mr. Schlager saw the book through the press and undertook to provide the index.

THE AUTHOR.

LEIPZIG, *January* 1909.

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1 Centimetre	=	·393708 inch.
1 Metre	=	3·2808 feet.
1 Kilometre	=	1093·633 yards.
1 Gramme	=	15·4325 grains troy.
1 Kilogramme	=	2·2055 lbs. avoir.

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EXPERIMENTAL PSYCHOLOGY AND PEDAGOGY

INTRODUCTION

I. The Principles of Experimental Research

Descartes' famous saying, "Dubito de omnibus," is not only useful for the building up of a system of philosophy, but also for the foundation of a new science. For in both cases will he fare best who accepts no general statement without sufficient proof. And so it often happens that such a person finds the most important questions and the most difficult problems in things that "common sense" takes as a matter of course.

Psychology has been trying for more than a generation, and pedagogy for more than ten years, to build up anew their departments of knowledge. This being so, both sciences can make good use of Descartes' famous saying. Let us see where the use of this principle in psychology and pedagogy will lead us.

Let us suppose we ask somebody the very trivial question whether the taste of sugar is pleasant or unpleasant. This question is purely psychological, because we do not seek any information about an outside object or about an objective process. We seek information about a process that takes place in our consciousness, and we do not raise the question as to the possibility of an objective process (say, a certain process in our nervous

system) being connected with the subjective process in our consciousness.

The answer, "Sugar tastes pleasant," will be given in the great majority of cases as if it were self-understood, and it will be difficult to persuade anyone that to raise a doubt here is anything more than a laughable eccentricity. But what if a real doubt did arise? The doubter would, of course, test the taste of sugar again, and then uphold his previous judgment with greater certainty on the ground of his latest experience. How does this greater certainty arise? Partly because he has had direct experience of the fact, but chiefly because he has paid special attention to it. Two conditions were carried out in this little experiment. Firstly, the individual in question knew the moment when the process to be observed would begin, and therefore could fix his attention on the expected occurrence. What would happen if we were to fall upon the person, so to speak, from behind with an unexpected stimulus, can be seen in the well-known experiment of mixing marzipan with potatoes. The sweet taste in this case can be absolutely repulsive.

It is not to be wondered at, then, if we demand in a scientific investigation a signal for the attention—"Ready" or "Now"—before every experiment, and also a definitely measured off length of time (one to two seconds) for the attention to get fixed.

Secondly, the attentive observation of the phenomenon must not be disturbed by anything. No one could expect anyone suffering from toothache to take part in our experiment on the taste of sugar. So also, no one would think of helping the observation of the process in question, by suddenly firing off a pistol near the subject of the experiment. On the contrary, everything that might distract the attention would be avoided.

We have thus arrived at two important rules of method :—

1. The observer must be prepared for the occurrence of the event.

2. The observer must follow the process of consciousness with close attention.

But Descartes' famous saying will not allow us to rest satisfied with a single experiment. The only possibility of freeing ourselves from lasting doubt lies in several repetitions of the experiment. Where from the nature of the case such a repetition seems impossible, as, for example, in dreams, we can never arrive at scientifically useful results. This is the reason for the aversion of our science to the investigation of so-called abnormal states of consciousness.

We therefore set up a third rule :—

3. Every observation must, for the sake of certainty in our results, be able to be repeated several times under exactly the same conditions.

It is only when we have carried out this principle that our method of procedure becomes what in the empirical sciences is called a scientific method of investigation. And in most cases it leads to a real extension of knowledge. And so it is in regard to our simple question. We discover first of all that we have formulated our question wrongly. For it appears that in tasting sugar a great number of sensations work together—sensations of taste, of touch, and of temperature—and that we arrive at quite different judgments as to our feeling, according as these sensations are mixed. A warm solution of sugar tastes otherwise than a cold one, for example. And we can never come to any result, if we do not thoroughly analyse the occurrence into its different elements and

investigate each particular element separately. Therefore our question must be first of all only: "Is a sweet taste pleasant or unpleasant?" Sensations of touch and temperature must be as far as possible prevented. There would remain as another quite different experiment, the investigation of the combined influence of these different elements upon our feeling. (Synthesis.)

Our fourth rule will then run as follows :—

4. The investigation must start with the elements of consciousness, and afterwards proceed to the investigation of the complex processes.

I will give here a number of statements that I obtained in experiments on the influence of sweet and sour taste on the feelings.[1] Subject A., Solution of sugar :—"A feeling of pleasure has not arisen. Perhaps I was disappointed at the weakness of the taste."[2] On another occasion, with the same solution of sugar, the judgment "pleasant" was given. Because of the uncertainty of the judgment, I then took a stuff with a stronger sweet taste, *i.e.* saccharine, and first gave a weak solution. The judgment was: "The stimulus is too weak; no positive feeling of pleasure, rather the opposite; sweetly oily."

I then gave a stronger solution. Answer: "Bittersweet, unpleasant."

With a medium solution, the judgment was: "At first unpleasant, then it slowly changes to a weak feeling of pleasure."

And so we arrive at the method of giving a graduated series of sensations of sweetness, from a very weak to a

[1] The changes of the pulse and breathing that took place during the experiment were also registered. (*Cf.* pp. 123–124.)

[2] The same subject in the next experiment, in which a solution of vinegar was given to taste, remarked: "This tastes refreshing, and not unpleasant. More pleasant than in the former experiment." The temperature of both solutions was exactly the same.

very saturated solution. We obtain then a graduated series of judgments corresponding to the series of stimuli. Comparing these two series, we find a certain regularity in the relations between stimulus and sensation, and between sensation and feeling—a sort of psychological law, which for Subject A. would run somewhat as follows:—Weak solutions of sugar taste indifferent or unpleasant, very strong solutions unpleasant. Solutions of a middle strength taste pleasant. (The strength of the solutions would be given according to the percentage of sugar contained.)

On the basis of these considerations, we arrive at a fifth and last rule:—

5. We must in our experiments be able to alter the conditions we are investigating, under which a process of consciousness takes place, according to a definite plan, so that we may be able to deduce certain regularities from a comparison of the graduated series of stimuli with their corresponding effects in consciousness.

If we cast a glance over the five rules we have formulated, we find that they form a method of investigation that goes by the name of "experimenting."[1] This method of investigation has long been accepted as the best in all natural sciences. Both descriptive and explanatory natural sciences have arrived at their most important results by the aid of experiment.

By applying Descartes' rule to our simple psychological problem, we have been able to deduce all the conditions necessary for an experiment. We have arrived quite naturally at the experimental method. The method has grown as a matter of course out of our problem. We therefore conclude that this method is the natural method for psychological investigation.

[1] Wundt, *Psychologische Studien*, Bd. III. 1907.

It may not be possible in every psychological experiment to obey all the five rules we have formulated. There are perfect and imperfect experiments. If in a particular case only three of the rules can be obeyed, then we must endeavour to carry out these all the more conscientiously.

II. The Divisions of Experimental Psychology and Pedagogy

In the above-mentioned experiments on taste, certain striking individual differences came to light. For example, Subject B. gave this judgment about a certain solution of sugar: "This kind of sweetness is unpleasant." Whereas Subject C. remarked about the same solution: "Decidedly pleasant." Here we stand on the threshold of the psychology of individual differences, or individual psychology.

It further came to light that the greater number of the male subjects of our experiment felt the sweet taste to be scarcely pleasant or absolutely unpleasant. We have, however, reason to believe that for all young children a sweet taste is pleasant. And this brings us to the problem of psychical development, of ontogenesis, of the development of the individual. The most important part of ontogenetic psychology is, of course, child psychology.

And so through our simple experiment we have arrived at the following branches of experimental psychology:—

1. General psychology.
2. Individual psychology.
3. Ontogenetic psychology; in particular, child psychology.

One might also add phylogenesis, or the development of communities—a family, a people, a race, or mankind. The most important part of phylogenetic psychology is racial psychology. Experimental investigation is here,

of course, almost entirely impossible. But then the experimental method is not an absolute necessity. For the processes of consciousness do not, as in the above-mentioned divisions of psychology, form the objects of investigation, but rather definite mental products, such as language, custom, religion, and these are relatively constant objects in comparison to the ever-flowing processes of consciousness.[1] A method of simple observation is deemed sufficient for those natural sciences that deal with constant objects, say, for example, in the investigation and description of a mineral, whereas in investigating processes—*e.g.* a chemical change—the experimental method is absolutely necessary. So in racial psychology the method of observation is sufficient, and is indeed the only possible method. Moreover, racial psychology is only then of interest to pedagogy, when we can obtain definite results as to the laws of ontogenesis by a comparison of the mental products of the child with those of different races—*e.g.* a comparison of the drawings of children with those of primitive races.

Pedagogy, to give a very general definition, deals with the investigation of those methods which must be made use of in order to influence in a definite manner the development of a human being. This definition of pedagogy is different from that of normative pedagogy, which first sets up special norms or rules, and then seeks the means by which these ends are to be attained. The norms are taken from the normative sciences—*e.g.* ethics. On the other hand, our idea of pedagogy is that it must take into consideration all the possibilities of development, and then investigate by what ways and means these latent possibilities of development may be helped. Pedagogy has therefore first of all to test the ends set up by the nor-

[1] *Cf.* Wundt, *Outlines of Psychology*, Judd's translation, 3rd edition, p. 26.

mative sciences, and find out how far they can be attained; and further, it must investigate whether the attainment of the ends in question can be influenced by educational measures, and if so, at what stage of development these measures must be begun, and which stages are most favourable for further development.

If, for example, the normative sciences demand a development towards morality and religion, pedagogy has first of all to answer the following questions:—

1. What are the psychological foundations of morality and religion? The answer to this question must be sought for in general psychology or in racial psychology.
2. What individual differences are there? (Moral insanity, &c.) Individual psychology must answer this.
3. How do morality and religion develop in the individual child? At what stage of development does an understanding for moral and religious questions arise? At what stage is the interest in such questions greatest? Child psychology must answer these questions.

Only after settling these preliminary questions does the real pedagogical investigation begin. Since this always has to deal with stages of development which are meant to be influenced by definite pedagogical measures, the experimental method should be made use of whenever possible. The reason why this has seldom been the case up till now, is that this method had not been perfected.

First of all, experimental pedagogy has to settle the question by experiment, whether the mental and physical abilities can be influenced (by educational measures), and if so, to what degree. Then it must test the individual existing methods of education in respect to their usefulness in helping to attain a special end and in helping to attain the general end of education.

III. Anthropometrical Measurements

Pedagogy has in general to deal with the development of the whole human being, and in particular with the development of his mental faculties. Therefore, it has a direct interest in the development of the body, in as far as the training of the child's bodily faculties is one of its tasks, and an indirect interest, in as far as physical and mental development influence each other. This may show itself in a parallelism between the two, or in the fact that periods of increased physical development are accompanied by decreased mental development, and *vice versa*.

A further question arises, as to whether physical development is hindered by overmuch instruction—*e.g.* by admitting children to school at a very early age, or by overloading them with mental work.

From all these considerations, is anthropometry, the science of measuring the human body, of importance to pedagogy.

The most important anthropometrical measurements for pedagogy are :—

1. Height. With bare feet, heels close together and knees unbent.

2. Weight. This can best be taken during the swimming lesson. The swimming costume should be of a definite weight for all.

3. The capacity of the lungs. The exact amount of air exhaled can be measured by the spirometer (Fig. 1). The air enters an inverted air-bell, floating on water, and thereby moves the scale up, so that the number of cubic centimetres can be easily read off. The use of this apparatus with children presents certain diffi-

culties, so that measurements (with an ordinary tape) of the circumference of the chest, when the lungs are full and when they are empty, may suffice. During these measurements, the attention of the child should be diverted from his breathing, so that this may take place in a natural manner. The average of the two values

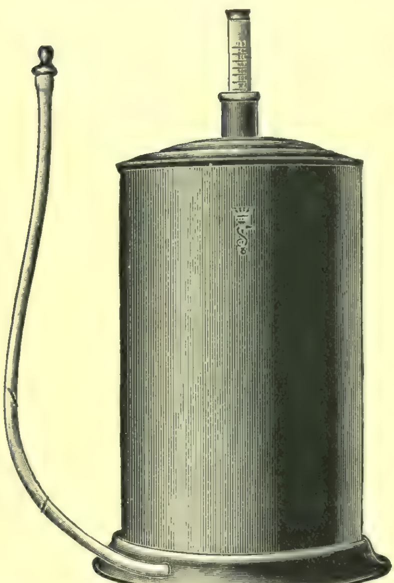


FIG. 1.—Barnes' spirometer.

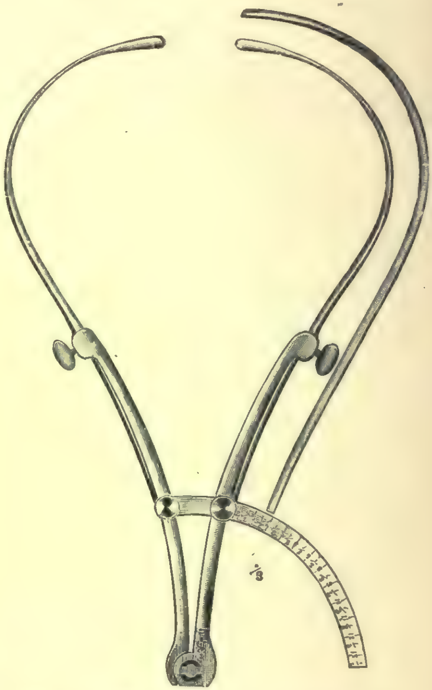


FIG. 2.—Flint's stethometer to measure the diameter of the chest.

thus obtained serves as a measure of the circumference of the chest.[1] The diameter of the chest can be measured by the stethometer (Fig. 2).

[1] Quirsfeld, "Zur physischen und geistigen Entwicklung des Kindes" (*Zeitschrift für Schulgesundheitspflege*, 1905), maintains, on the basis of his investigations, that the circumference of the chest has no direct influence on the vital capacity of the lungs.

4. The size of the head—
   (*a*) The circumference, by means of a steel measuring tape.
   (*b*) The length and breadth, by means of a rod (Fig. 3) or a compass (Fig. 4).

FIG. 3.—Peterson's head measure.

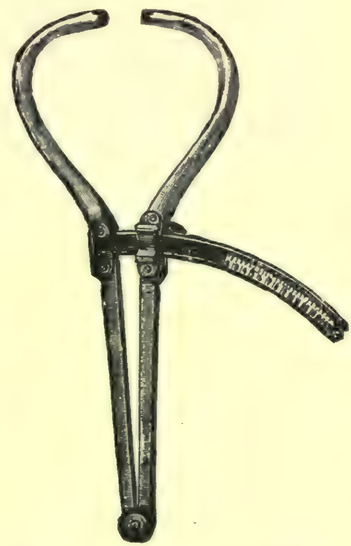


FIG. 4.—Bertillon's compass for head measurements.

   (*c*) The height, by means of the anthropometer. (Fig. 5 shows a measurement of the head with Krönlein's cephalometer.)

To establish cases of under-nourishment and of weakness due to illness, a measurement of the hand pressure is important.

5. The pressure of the hand can be best tested with the dynamometer.

This consists of a strong spring, which is pressed

together by the hand. This causes, by means of a small tooth-wheel, two pointers to move along a scale. When the pressure ceases, one of the pointers remains stationary at the maximum point, and then the greatest pressure attained can be read off in kilogrammes (Fig. 6). Figs. 7 and 8 show dynamometers for pressure and for pulling.

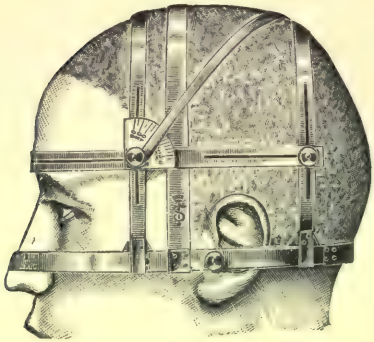


FIG. 5.—Krönlein's cephalometer.

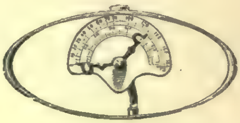


FIG. 6.—Collins' dynamometer.

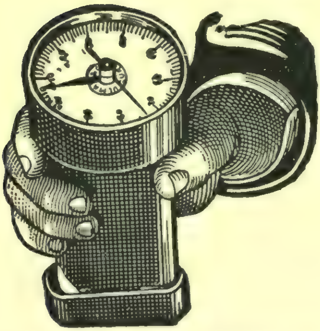


FIG. 7.—Ullman's dynamometer for squeezing.

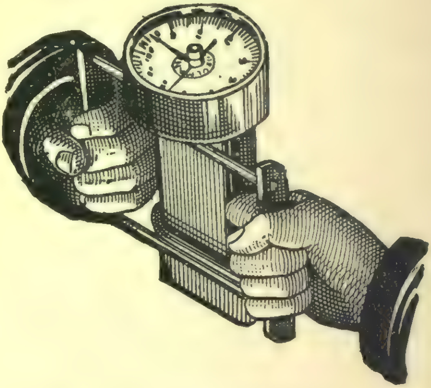


FIG. 8.—Ullman's dynamometer for squeezing and pulling.

The most important results of anthropometrical measurements are :—

1. The relative increase of the different parts of the body varies very considerably during normal growth.

A drastic example of this is given by the comparison

of the skull of a newly-born infant with that of an adult (Fig. 9).

The child is not a miniature edition of the adult, but a being in which certain organs are almost wholly undeveloped and certain others almost perfectly developed. We may conclude from analogy that the same relation will exist in regard to mental capacities, and experiments have confirmed this.

2. All development is rhythmical—*i.e.* the amount of increase is not the same each year; in some years it is quicker than in others.

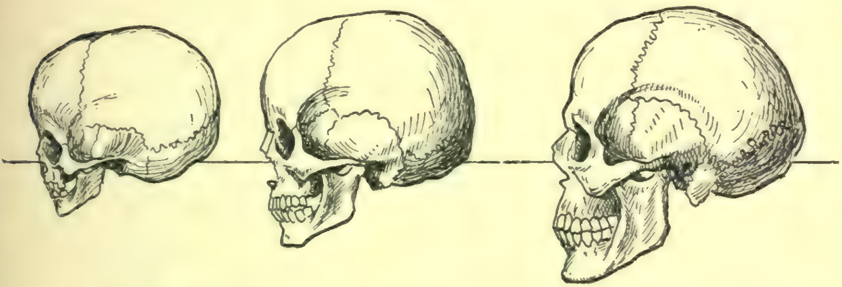


FIG. 9.—Skulls of one-year-old child, ten-year-old child, and adult.

(From Schmidt, *Unser Körper*. Voigtländer, Leipzig.)

For example, in regard to the height of the body, we can see from Fig. 10 that the greatest increase takes place between the ages of 14 and 15 (6·4 cm.). Between the ages of 10 and 11, we find a minimum increase in height (3·7 cm.). These results are taken from measurements of the pupils of a high school.[1] The girls of the Berlin elementary schools show a maximum at the age of 13 and a minimum between the ages of 11 and 12[2] (Fig. 11).

[1] Dr. A. Koch-Hesse, "Ein Beitrag zur Wachstumsphysiologie des Menschen," *Zeitschrift für Schulgesundheitspflege*, 1905.

[2] Noteworthy is the fact that girls are smaller than boys up to the age of 11. From then on to the age of 15 they grow quicker than boys.

These relations differ according to sex, race, climate, and especially in regard to the environment in which the child grows up. Poor children develop slower than rich ones.

In general, the fact is established that the period of

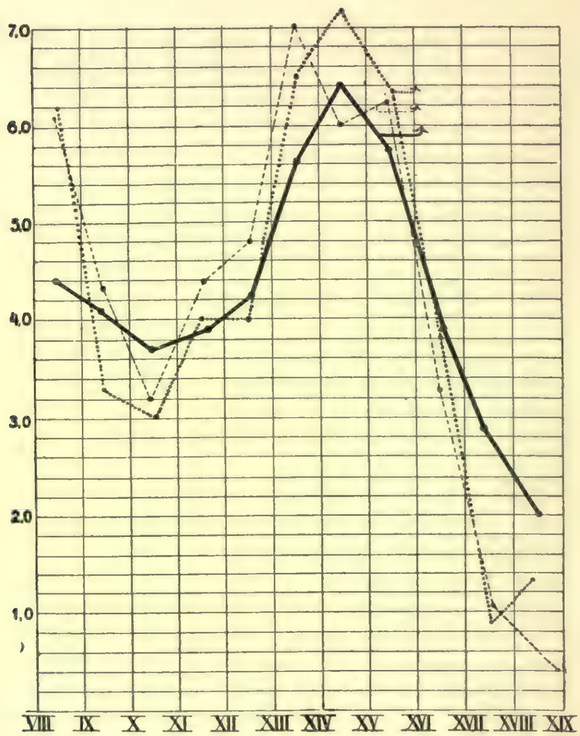


FIG. 10.—Curves of the absolute annual increase in height of Jena school-children.

(From Koch-Hesse, *Zeitschrift für Gesundheitspflege.* Voss.)

maturity is the period of most rapid growth. Another maximum appears between the ages of 8 and 11. Between these two periods lies a period of slow growth. The pedagogical importance of these facts is self-evident.

This rhythmical progress can be shown in all anthropo-

metrical measurements, although, of course, the maxima by no means always fall in the same period. It is well

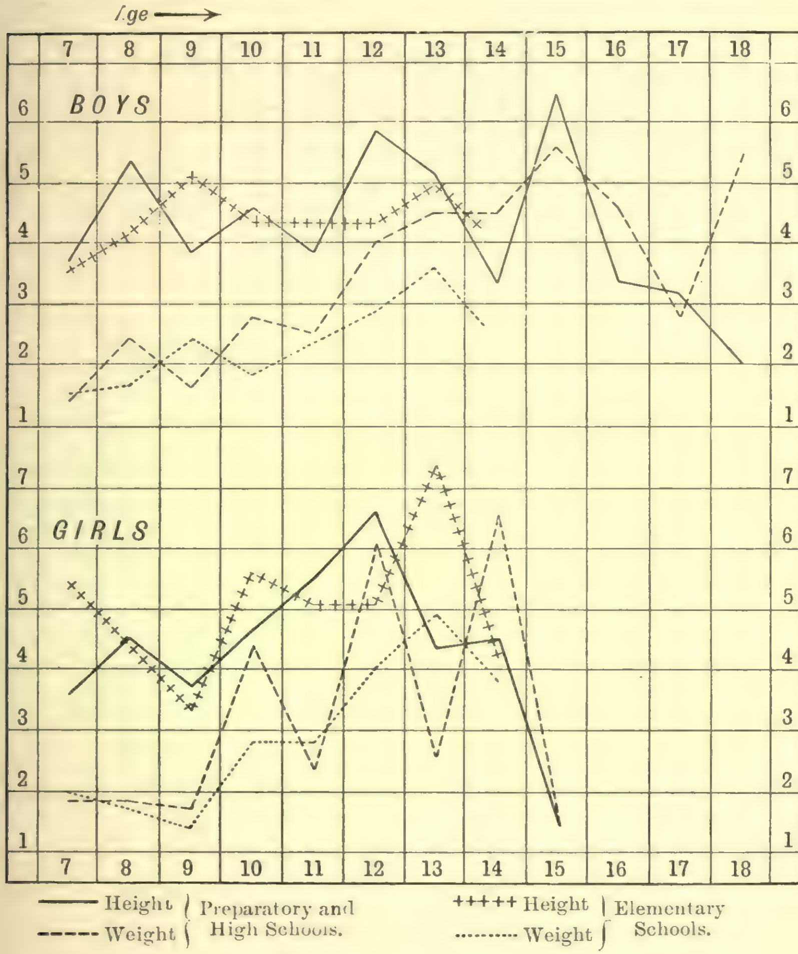


FIG. 11.—Increase in weight and height of Berlin children.

(From Rietz, *Archiv für Anthropologie*, Bd. 29. Vieweg & Sohn.)

known that the growth in height comes to an end in the period of youth, while great changes may afterwards take place in regard to weight.

And so it is with mental development. Therefore it is our task to fix the general mental condition at each grade of instruction, and also the mental capacity of the child for each particular subject at each particular grade.

Besides these large fluctuations in physical development, smaller fluctuations within the period of a year have been observed.

It is, of course, extremely difficult to arrive at universally valid results, because each child again shows individual peculiarities in its growth. So we cannot be surprised that the science of anthropometry has up till now been able to set up very few universal laws. For example, it cannot yet definitely answer the question as to whether the first school-year hinders the physical development of the child or not.

Most important for all such investigations is a familiarity with the methods of mathematics. For only then can we make our figures alive, only then can we make them speak.

CHAPTER I

THE MATHEMATICAL TREATMENT OF RESULTS IN CHILD PSYCHOLOGY AND PEDAGOGY

I. MEASUREMENTS IN PHYSICS

1. The Law of Error

As soon as measurements of any kind are undertaken, errors are bound to appear. Speaking strictly, no measurement is absolutely free from error. In measuring the length of a certain rod, for example, I got the first time 100·1 mm., the second time 99·9 mm., and so on. Therefore, if I wish to make a definite statement as to the length of this rod, I must take a number of measurements. In measuring it eighty times, I obtained lengths that fluctuated irregularly from 99·6 to 100·4 mm. The different tenths of a millimetre between 99·6 and 100·4 mm. did not all appear the same number of times, but as follows :—

Lengths.	No. of Times.
99·6 mm.	1
99·7 "	3
99·8 "	8
99·9 "	17
100 "	22
100·1 "	17
100·2 "	8
100·3 "	3
100·4 "	1

If I measure off the tenths of a millimetre on a horizontal line (abscissæ), and the number of times on a vertical line

(ordinates), I can draw a curve. (Fig. 12.) We see at once a certain regularity in the distribution of the errors, although during the measurements they appeared to arise quite irregularly. The "error" curve is absolutely symmetrical. The right half is exactly the same as the left. The curve rises at first very slowly, and then more quickly. In the middle, at the top, it is comparatively flat. Now, this kind of curve appears in all kinds of measurements. It is the same if I measure the length or the breadth or any other quality of an object. From this regular distribution of errors, we arrive at a certain

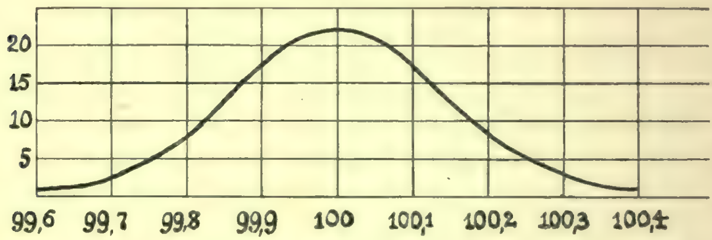


FIG. 12.—Distribution curve of eighty measurements of a rod.

law, which is called the Law of Error,[1] and to which all physical measurements are subject.

The working out and proof of this law belongs to the Theory of Probability. Without going deeper into this theory, we can nevertheless obtain an insight into the nature of the Law of Error by a few elementary considerations. First of all, it is easy to understand that our measurements of the length of the object are too long just as often as they are too short. For there is no reason why the one measurement should have an advantage over the other. Hence the symmetry of the curve is explained. It is also quite obvious that the larger errors (99·6 mm.

[1] The "error" curve was first established and proved by Gauss, and the law is therefore often called Gauss's Law.

and 100·4 mm.) appear very seldom, and that the frequency of the error increases according as the error becomes smaller. And that explains the general shape of the curve. As to the height and breadth of the curve, we can say nothing *a priori.* But these two characteristics are not of fundamental importance; they change merely according to the number of measurements taken, the accuracy of the measuring instrument, &c. Of fundamental importance is the form of the curve.

2. The Arithmetical Mean

Since in our measurements the accidental errors are symmetrically grouped, the arithmetical mean of all the single measurements will give us the real length of the measured object.

Let n equal the number of measurements carried out (in our case 80), and let a_1, a_2, a_3, . . . a_n, stand for the separate measurements—99·6 (once), 99·7 (three times), &c.; then to get the arithmetical mean (A), I must take the sum (Σ) of all these separate measurements, and divide this by the total number of measurements (n).

$$A = \frac{\Sigma a}{n}$$

Substituting my figures—

$$A = \frac{8000}{80} = 100 \text{ mm.}$$

This would, as a rule, satisfy the interests of physics, because it is only concerned with getting at the length of the object in question.

3. The Distribution of the Errors

But we might ask a further question: What was the magnitude of the errors that appeared in our measurements? To answer this, we could take the greatest and

the least number (100·4 and 99·6 mm.) or their difference from the arithmetical mean, and say, "The maximal deviation (above and below) is in both cases 0·4 mm." Such a statement, however, would scarcely be precise. For it can easily be imagined that by some unfortunate occurrence we might get a figure that deviates very considerably from the mean (say, by 2 mm.). If this one figure were given to describe the accuracy of the measurement, it would give quite a false view.

Therefore it is always best to calculate the average error (E_m). Let us call the differences of each measurement from the arithmetical mean Δ_1, Δ_2, . . . Δ_n (Δ = difference). Δ_1 and Δ_n, for example, in our case are each equal to 0·4 mm., and so on. I then take the sum of all these differences ($\Sigma\Delta$), and divide it by the total number of measurements (n).

The average error is therefore—

$$\mathbf{E}_m = \frac{\Sigma\Delta}{n}$$

Working this out, I get—

$$\mathbf{E}_m = \frac{92}{80} = 1{\cdot}15 \text{ tenths of a millimetre.}$$

This value is a measure for the accuracy of our observations or for the distribution of the errors.

An objection to this calculation might be raised. A large error (say, of 2 mm.) that happens by chance would have too great an influence on our calculation. The above example would then be changed from $\frac{92}{80}$ to $\frac{108}{80} = 1{\cdot}35$, a considerably larger value. Therefore in very exact investigations the probable error (PE), and not the average error, is taken as a measure for the accuracy. All the errors (in our case 80) are arranged in order of magnitude, and the middle one is chosen (in our case No. 40), counting

either from the smallest or the largest.[1] There are, then, counting from this middle error, as many large errors as smaller ones. Therefore this error gets the name of the probable error. Then the probability of errors of smaller or of greater magnitude occurring is equally great. The probable error will always be a little smaller than the average error, because according to this method of calculation the extreme errors of great or small magnitude do not play so important a part. It has been established that the probable error always amounts to $\frac{4}{5}$ (or, more precisely, ·8453) of the average error.

$$PE = \pm \cdot 8453 \cdot \frac{\Sigma\Delta}{n}$$

In our example, therefore—

$$PE = \pm \cdot 8453 \times 1\cdot 15 = \pm \cdot 972 \text{ tenth of a millimetre.}$$

If I always carry out my measurements with the same instrument and with the same conscientiousness, the measure of accuracy (the average or the probable error) will remain the same, whether I measure a length of 10, 20, or 100 cm. If, therefore, the accuracy of an instrument is once and for all settled, the calculation of the measure of accuracy for a special object is of little importance for the physical scientist.

Each observer has, however, his own measure of accuracy, according to the acuteness of his senses, his conscientiousness, &c. In Fig. 13 we see the error curve for two observers. The observer B. (the dotted line) is the better of the two. The maximum and minimum of deviation are smaller, and the errors group themselves more

[1] If the smallest error is 1 and the largest 20, the middle need not lie at 10. For if there are a number of errors of the value 1 and also of the value 2 or 3, the probable error may be 3. By this method of reckoning, one large error of the value 20 or 100 makes no difference. Of fundamental importance is the space where most of the errors crowd together.

about the middle. The value 100 mm. appears thirty-three

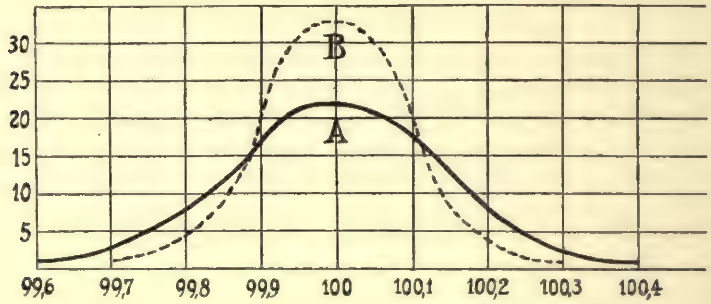


FIG. 13.—Error curves of two observers.

times, instead of only twenty-two times as with observer A. B.'s average and probable error are smaller than A.'s.

4. The Probable Error of the Arithmetical Mean

We have up till now taken for granted that the real size of the measured object is the same as the arithmetical mean of the separate measurements. This is true only in the case of a very great number of measurements, or, strictly speaking, of an infinite number. Only in this case does the arithmetical mean really correspond to the real size of the object, and we can then say that the error is equal to nothing. If, on the other hand, I had only taken one measurement, I would not be able to make any statement about the probable error. Therefore the more measurements I take, the greater will be their accuracy, and the smaller will be the probable error of the arithmetical mean. One might then imagine that by a hundred times as many measurements the error would be a hundred times as small, but it has been proved that it is only ten times as small ($\sqrt{100}$). If I therefore divide the previously calculated probable errors of all the separate observations by $\sqrt{100}$ (or generally, the root of the

number of observations, $\sqrt{n}$), I shall obtain the probable error of my arithmetical mean.

$$PE_m = \frac{PE}{\sqrt{n}}$$

In our example—

$$PE_m = \frac{\cdot 972}{\sqrt{80}} = \cdot 109 \text{ tenth of a millimetre.}$$

This value is of great importance to the natural scientist, because it is really a measure of the accuracy of the statement that the measured object is 100 mm. long.

The formulæ that we have so far given are accurate enough, when more than ten measurements are taken. Other formulæ have been found to be better for a smaller number of measurements. We give below the simple formulæ for reckoning the error that we have just discussed, and append thereto the more accurate formulæ (Nos. 1*a*, 2*a*, 3*a*).

The simple Formulæ.

1. Average error—

$$E_m = \frac{\Sigma\Delta}{n} \qquad E_m = \frac{92}{80} = 1\cdot 15$$

2. Probable error of the separate observations—

$$PE = \pm \cdot 8453 \cdot \frac{\Sigma\Delta}{n} \qquad PE = \pm \cdot 8453 \times 1\cdot 15 = \pm \cdot 97$$

3. Probable error of the arithmetical mean—

$$PE_m = \frac{PE}{\sqrt{n}} \qquad PE_m = \frac{\cdot 97}{\sqrt{80}} = \cdot 11$$

More accurate Formulæ.

1*a*. Average error—

$$E_m = \sqrt{\frac{\Sigma\Delta^2}{n-1}} \qquad E_m = \sqrt{\frac{184}{79}} = 1\cdot 53$$

2*a*. Probable error of the separate observations—

$$PE = \pm \cdot 6745\sqrt{\frac{\Sigma\Delta^2}{n-1}} \qquad PE = \pm \cdot 6745 \times 1 \cdot 53 = 1 \cdot 03$$

3*a*. Probable error of the arithmetical mean—

$$PE_m = \frac{PE}{\sqrt{n}} \qquad PE_m = \frac{1 \cdot 03}{\sqrt{80}} = \cdot 12$$

Formula 1*a* requires all errors (Δ) to be raised to the square root, to be added together ($\Sigma\Delta^2$), and to be divided by n—1. The square root of the value thus obtained must then be taken. Formulæ 2*a* and 3*a* follow quite obviously. Note the fact that even with eighty measurements the accuracy of the simple formulæ is very great.

II. MEASUREMENTS IN BIOLOGY

1. The Subjection of Biological Quantities to Natural Laws

If a great storm occurs during the herring-season, and if the shoals happen to be near land, then hundreds and thousands of herring are cast upon the shore and die. The anger of the waves seems to make no distinction among the hundreds of thousands of these creatures that it condemns to death. No one who has witnessed such an occurrence can help feeling pity for the destruction of so many living beings, whether he has a direct interest in it as fisherman or tradesman or whether he be merely a lover of nature. And only very few know that such natural phenomena are subject to definite natural laws, that even here so-called chance acts according to a special law. A mathematician took the trouble to obtain measurements of many thousands of the dead animals—of the length of the whole body, of the head, of the fins, &c. He found a great number of very small and very large animals. The medium size of fish was scarcely found at all; and the

more the animals approached this medium size, the fewer there were. The same was found to be the case with regard to the length of the various parts of the body. Animals with very long or very short tail-fins were more common than the medium kind. When the same observer took the same measurements of the fish caught at sea, it appeared that the great majority of these belonged to the medium size, and that, with the same regularity as before, the numbers of small and large animals this time decreased in proportion to their size. This regularity was found to correspond exactly to what we have seen in measurements in physics—in short, to Gauss's Law of Error. We can, then, in this case also, in accordance with our law, fix a mean value and an average or probable error of deviation from the mean. The mean value represents the common type of fish, and the mean deviation gives us the extent of variation from this type. We see to some extent the tendency of nature always to reproduce these animals according to a definite size and to definite proportions. And we assume with certainty, that the working of the law of heredity, by which the offspring in general is exactly similar to the parents, is a sufficient reason for the appearance of this mean value. The extent of variation represents the extent of the general conditions under which the animal lives. Further, the average strength of the storms settles the limits within which the average animal can exist; the animal that is too large or too small perishes. Within these limits fixed by heredity and by average conditions of existence, exists another division according to the accidental conditions of existence of each separate animal (the different kinds of food it may obtain, &c.); and in consequence of these accidental conditions, the form of the curve must be the same as that of Gauss's error curve, which also arises from purely accidental factors in measuring any physical phenomenon.

This average error, which has little importance in physics, is in biology of the greatest importance. It gives, as the so-called extent of variation, the limits within which those individuals grouped around the mean value may be called normal.

These laws are valid for all organisms, and also for human beings. The measurements here are, of course, more difficult than those in physics. Thoma,[1] for example, found that very large errors appear in simple measurements of the height of a human being. In taking several successive measurements of a child, errors of 4 or 5 mm. appeared in spite of the greatest caution. However, if we measure a very great number of individuals, the law of error is clearly seen. Fig. 14 shows two curves: the continuous line shows the Gauss curve calculated according to the mathematical laws; the dotted line the distribution according to height of 2192 American school-children (eight-year-old girls). For example, 2 girls were 137 cm. high, 8 were 135 cm., &c.; 300 girls attained the average height of 120 cm., 3 were 103 cm. high, and only 2 were 100 cm. Note how accurately the dotted line corresponds to the ideal curve.

The scientists who first of all recognised the fact that life and death and all conditions of human existence are subject to definite laws that can be represented in figures, were filled with awe at the regular working of nature. Süssmilch, the author of *Die göttliche Ordnung in den Veränderungen des menschlichen Geschlechts*, writes: "The all-wise creator and ruler of this world brings forth out of nothing the numberless army of human beings. The infinite being allows us for a certain time to bow down in reverence before His presence, until, our time completed, we must leave the scene of this world. Our entrance,

[1] R. Thoma, *Untersuchungen über die Grösse und das Gewicht des menschlichen Körpers*, Leipzig, 1882.

our passing before the eyes of the Lord in this world, and our exit, all take place according to a most wonderful law."

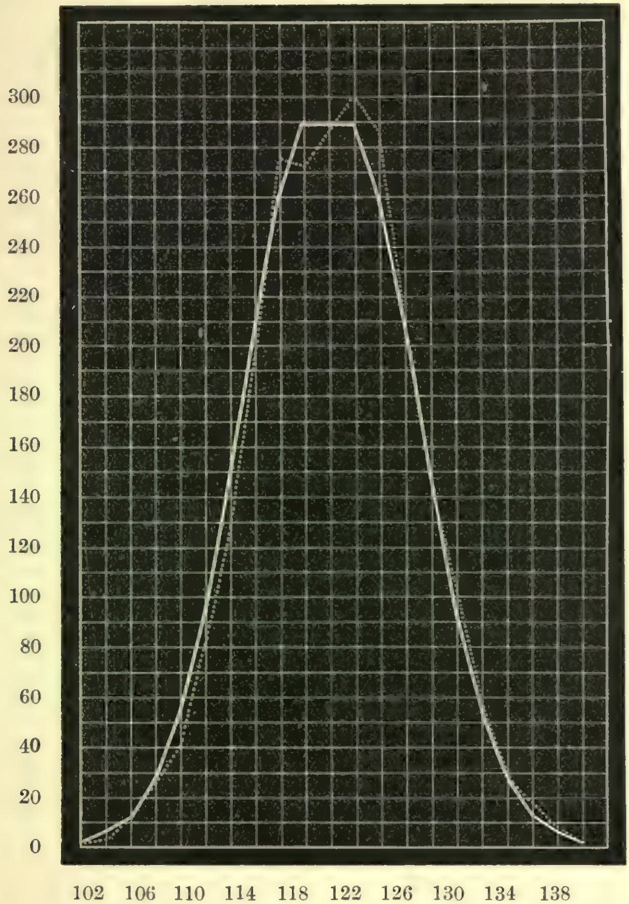


FIG. 14.—Distribution curve of the height of 2192 eight-year-old girls of St. Louis according to Gauss's law (continuous line) and according to the real observations (dotted line).

(From Townsend Porter, *Zeitschrift für Ethnologie*, 1893. Asher & Co.)

2. Gauss's Law of Error

In the year 1863 Fechner took measurements of over 200 rye-stalks of six joints each, which he obtained from a

field in the neighbourhood of Leipsic. The second joint of the stalks gave, for example, the following measurements :[1]—

No. of Times.	Length.	No. of Times.	Length.
1 . . .	19 cm.	30 . . .	35 cm.
1 . . .	21 ,,	31 . . .	37 ,,
2 . . .	23 ,,	32 . . .	39 ,,
7 . . .	25 ,,	26 . . .	41 ,,
7 . . .	27 ,,	16 . . .	43 ,,
16 . . .	29 ,,	7 . . .	45 ,,
18 . . .	31 ,,	1 . . .	47 ,,
26 . . .	33 ,,	2 . . .	49 ,,

Arranging these figures on a curve, we get Fig. 15. The form of this curve is like that of Gauss's error curve, except that the summit of the curve has shifted slightly to one side. We could imagine the curve to have been made up out of two halves of error curves, in which the average error (or mean extent of variation) for each half is different. Fig. 16 shows such an asymmetrical curve without the unevenness due to the comparatively small number of single measurements.

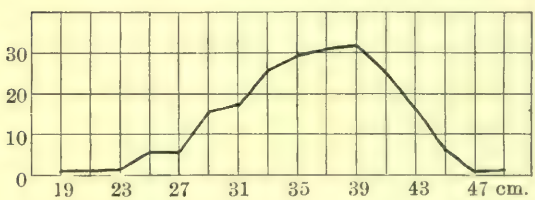


FIG. 15.—Distribution curve of the lengths of the second joint of 217 rye-stalks from a field near Leipzig.

(From Fechner's *Kollektivmasslehre.*)

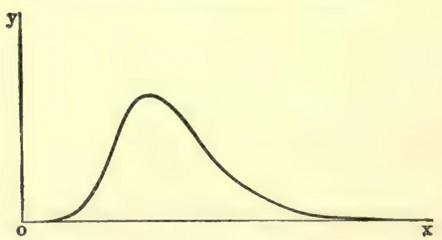


FIG. 16.—Asymmetrical distribution curve.

(From *Archiv für Anthropologie*, Bd. 30. Vieweg & Sohn.)

[1] Fechner, *Kollektivmasslehre.*

On closer investigation, we find that such an asymmetrical curve always arises when we try to fix a normal type in biology. (*Cf.* Fig. 17.) Even the curve in Fig. 14 shows on closer examination a slight asymmetry.

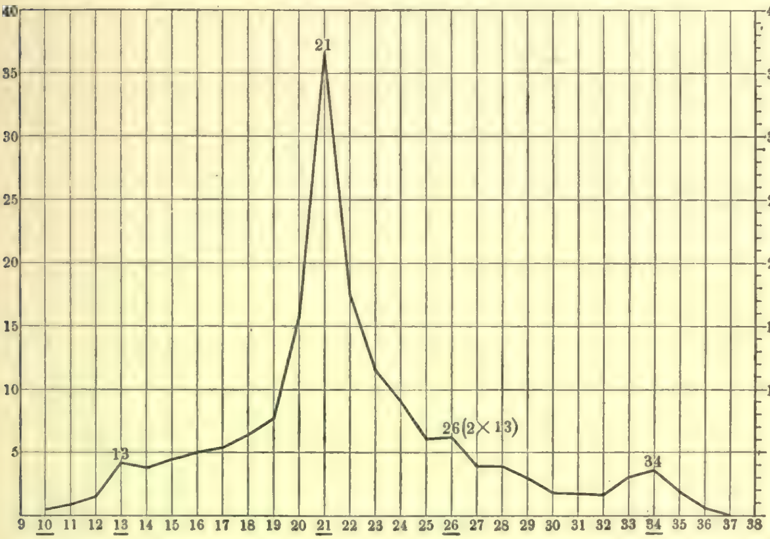


FIG. 17.—Number of radiate flowers of 17,000 heads of the *Chrysanthemum leucanthemum* according to Ludwig.

(From Ranke and Greiner, *Archiv für Anthropologie*, Bd. 30. Vieweg & Sohn.)

This can be seen from the fact that the greater part of the left half of the dotted line lies within the continuous line, whereas the right half of the dotted line falls outside of it.

The reason for the asymmetry of biological distribution is difficult to prove theoretically, but it can be easily made clear by practical examples. We can easily imagine that a very slight shortening of the normal length of the tail-fins of the herrings might make these animals incapable of fighting successfully against the elements;

whereas a much greater extent of variation in the breadth of the fin may be possible before this would do harm to the animals owing to its unmanageableness—*i.e.* the muscles of the fish might not be able to manage these large fins in a heavy sea.[1]

We must accept, then, this asymmetrical distribution for biological quantities, and it follows that our calculation will be different from that for physical measurements. As regards the chief value, we see at once that the arithmetical mean will not represent the normal type, but rather that value which appears most often, the average density, so-called because at this special point the number of observations are most dense. In Fig. 15, for example, the average density is 39 cm., because this value appears with the greatest frequency, namely, thirty-two times. The arithmetical mean, on the other hand, is only 36 cm., a value that obviously does not represent the normal type.

The so-called "central value," or median, is also often used as a measure in asymmetrical curves. To find this, all the values are arranged in order according to size, and the middle or central one is chosen. In the above example, the lengths of all the 217 stalks would be arranged in order, and the 109th one would be chosen. This one has a length of 37 cm. The central value always lies between the arithmetical mean and the average density, and

[1] From a purely mathematical standpoint, the asymmetry of biological quantities can be thus explained :—A symmetrical arrangement can only be expected where there is an infinite number of independent causes of errors. In such a case, it is taken for granted that the positive errors will balance the negative ones, because there is no reason for an opposite view. Where, however, special laws are at work, as in the biological laws of growth, an asymmetrical curve must always be expected. The height of a tree cannot increase indefinitely beyond the normal height, because it would not then be able to withstand the storms ; and similarly the other half of the curve will sink slowly down to the height of the smallest dwarf-trees.

therefore approaches the latter more nearly than the arithmetical mean does. We give these three values in our example :—

The arithmetical mean	=	36 cm.
The central value or median	=	37 „
The average density or mode	=	39 „

If only a few measurements have been taken, the central value is sufficient, and it is easier to arrive at than the arithmetical mean. With a great number of measurements, the density value appears in the curve without any further calculation, because here the greatest number of observations crowd together. This value should, then, have the preference.

After fixing the density value, we must reckon out the average error for each side of the curve, and out of this we get the extent of variation, which is, of course, asymmetrical, reckoning from the average density.

In our example the density value is 39. We then take the sum of all the deviations that lie above ($\Sigma\Delta^a$), and divide it by the total number of deviations above the density value (n^a). We therefore get for our average error of this upper half of the curve (E_m^a), according to the simple formula on page 23—

$$E_m^a = \frac{\Sigma\Delta^a}{n^a}.$$

We now carry out the same calculation with the lower half of the curve, dividing the sum of the deviations below ($\Sigma\Delta^b$) by the total number of these deviations (n^b). This gives as a mean deviation below the density value—

$$E_m^b = \frac{\Sigma\Delta^b}{n^b}.$$

Instead of saying "average error," it would in this case be better to say "mean variation" (${}_mV$). Accordingly

the following values would characterise a biological distribution :—

1. The density value, representing the normal type of the object investigated.
2. The mean variation, above and below this normal.[1]

Lastly, the probable error of the density value can also be calculated, either for the upper or for the lower half of the curve. According to the formula on page 23, and calling the probable error of the density value PE_D, we get two formulæ :[2]—

$$PE_D = \frac{{}_mV^a}{\sqrt{n^a}},$$

or

$$PE_D = \frac{{}_mV^b}{\sqrt{n^b}}.$$

The importance of these formulæ in the measurements of school-children will be shown later.

3. Measurements of a Collective Object

In order to arrive at exact measurements in physics, we carry out a number of measurements of *the same* object, and then take the arithmetical mean. In biology, where we deal with a whole class or species of objects, of

[1] It is obvious that on the side of the curve, where the ${}_mV$ is greater, the greater number of observations must lie, and also that the number of observations must be proportional to the size of the mean variation—

$${}_mV^a : {}_mV^b = n^a : n^b.$$

$${}_mV^a = \frac{\Sigma\Delta^a}{n^a},$$

$${}_mV^b = \frac{\Sigma\Delta^b}{n^b}.$$

[2] The probable error will not be the same in both cases. This arises from the fact that a greater number of observations occur in the one case than in the other.

which the separate representatives are measured, we are trying to arrive at the normal type. This whole class or species Fechner calls a collective object, because we are here concerned with a collection of objects. To arrive at real values, it is desirable to measure all the individuals of the class in question—*e.g.* all human beings. If this is impossible, I must limit my class. I can, for example, measure all adult Germans (*cf.* the measurement of recruits) or all twelve-year-old girls in Berlin, &c. Boys and girls should naturally not be measured together, because I know in advance that the bodily proportions of the two are different. If in any district there are very marked racial differences, I must then measure each race separately.

Very special attention must be given to the cases where, instead of one type, two types appear, because of the great change wrought on natural conditions by artificial influences. It has been established that children of well-to-do parents differ greatly in their measurements from those of poor parents, and also that the rapidity of bodily development is quite different. These differences appear to be very great, so that children of the same age of rich and poor parents differ more than children of the same age of different races. Anthropometry must devote great attention to these facts, since they are of much importance for national education. If the gulf between the two classes were to go on increasing, it would lead to a much-to-be-regretted decay of the unity of the nation. This could only be combated by a systematic equalisation of the conditions of life during the period of development (a universal system of elementary education, &c.).

In most cases it is impossible to measure all the individuals belonging to a collective object. The necessary choice of individuals must therefore be made with the greatest caution. For example, if I wish to obtain a measure for the ears of corn in a certain cornfield, it would,

of course, be absurd to take as samples only those that grow at the edge of the field. If I am measuring the size of heads, I must obviously exclude abnormal cases, such as hydrocephalus and microcephalus cases. Measurements of a collective object nearly always, as we have seen, give us an asymmetrical curve, and so our general rule must be: Do not be sparing in the number of observations. Several hundred, better still several thousand, are needed for one curve of distribution, if we wish to obtain exact results.[1]

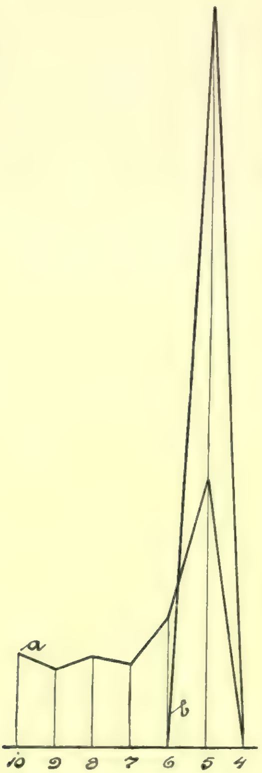


FIG. 18.—Variation curve of a plant (*Sedum spectabile*) under influence of white (*a*) and red (*b*) light.

(From Klebs, *Archiv für Entwicklungsmechanik*, 1907. Engelmann.)

4. The Influencing of Biological Quantities by Experiment

Curve *a* in Fig. 18 was arrived at in the following manner. 1370 flowers of a certain plant (*Sedum spectabile*) were taken, and the filaments (four to ten) of each flower were counted and the frequency of their occurrence marked upon the curve. The normal type is characterised by five filaments, the deviation above is about 2, the deviation below is very minute, because, as can be seen, there are very few flowers with four

[1] The recently recommended method of taking a comparatively small number of normal individuals is not reliable, since what is counted as normal is left to the caprice of the observer. Such measurements do not describe normal beings, but rather ideal beings, and often the most preposterous conclusions are arrived at on the basis of such investigations.

filaments. These figures—density value, 5; deviation above, 2; below, 0—give a sufficient mathematical description of the phenomenon. We can see here very clearly what a false picture would arise, if we were to give the arithmetical mean (about 6). It would give rise to the notion that the great majority of flowers had six filaments, which is not the case.

Curve *b* shows the same plant grown in a glass-house with red glass. Here we have almost wholly flowers with five filaments. If we had only calculated the arithmetical mean in both cases, it would give rise to the opinion that a plant with six filaments had been changed to one with five by the influence of red light. In reality, however, it is different. The value of greatest frequency (5) is the same, but all the more profuse flowers have been hindered in their development by the action of the red light. We see, therefore, that only a complete description of a collective object, with the density value and the extent of variation above and below, illustrates sufficiently the changes that take place due to special influences acting upon the process of growth.

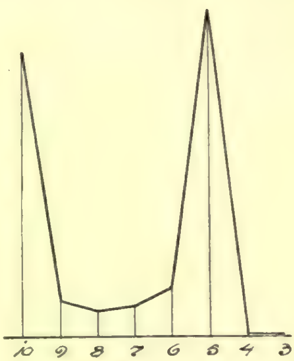


FIG. 19.—Variation curve of the filaments of the *Sedum spectabile* under the influence of chemicals.

(From Klebs, &c. See Fig. 18.)

The curve with two maxima in Fig. 19 arose in the following manner. The same plant as in the former experiment was allowed to grow for a certain time under normal conditions, until a number of flowers had appeared. Then a certain chemical substance was allowed to influence the growth. The individuals measured (the flowers) thus arose under quite different conditions—the

first half under normal, the second half under abnormal, conditions. We have here, so to speak, two different types or races.

The calculation of a middle value in all cases of curves of two or more maxima is useless. We must here investigate whether there are not two races present, or whether the one set of the individuals investigated has not grown up under conditions different from those of the other set.

III. MEASUREMENTS IN PSYCHOLOGY

Whoever undertakes to describe psychological processes in accurate figures, will soon discover what great difficulties present themselves. Suppose we are successful in measuring some way or other a sensation of brightness,[1] yet it is absolutely impossible for us to measure the same sensation again and again. For every sensation, in fact every process of consciousness, is, when it has once passed, irretrievably lost, and will never return in exactly the same form. Since for exact measurements I require a great number of individual measurements, I can only get over the difficulty by measuring a number of similar sensations: for example, say a number of sensations which arise in a normal state of consciousness due to the stimulus of a definite degree of brightness. We measure, so to say, a number of separate individuals—*i.e.* the separate sensations—and then we determine the normal type of this whole class or species of sensations. It is obvious, therefore, that psychological quantities can only be treated mathematically as collective objects. The methods we employ here are therefore similar to those of biology.

[1] The possibility of such measurements will be shown in the following chapters.

We must expect also in psychology asymmetrical distribution, and we must calculate the density value and the extent of variation above and below.

Let us take for granted that a certain individual can be put into certain states of emotion in most cases by the application of even a very small stimulus (say by sensations of temperature). If we took a certain number of measurements, the density value of our figures would mean a great sensitiveness of the subject in question. Again, if the mean variation of one such subject was large, and of another small, this would show an unreliable and reliable nature respectively (reliable in the sense that we can rely upon a person to react in a definite manner to a definite stimulus, or act in a definite manner according to given motives).

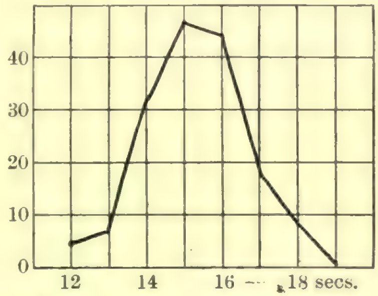


Fig. 20.—Distribution of the ability to copy out single digits.

Fig. 20 shows the productive power of an adult in copying out digits for a period of several hours. The time taken to copy out each set of 25 digits was registered, with the following results :—

4	times	he took	12	seconds.
7	„	„	13	„
32	„	„	14	„
47	„	„	15	„
44	„	„	16	„
18	„	„	17	„
8	„	„	18	„
1	time	„	19	„

Note the similarity of this curve to Gauss's error curve ; note also the slight tendency to asymmetry.

If psychological observations on one and the same individual are to be treated mathematically as a collective

object, much more so must observations on groups of individuals be similarly treated.

In the products of human culture, in the language, religion, and art of a people, certain psychological processes are to be found, as it were, fossilised. These, as we have mentioned above, form the subject-matter of racial psychology, and they can also be subjected to measurement.

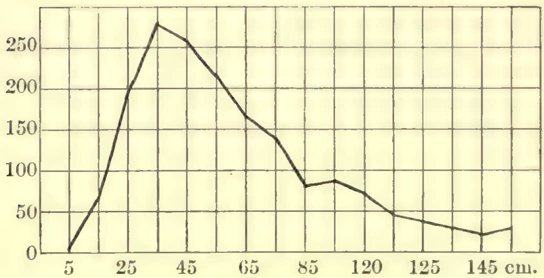


FIG. 21.—Distribution of 1794 pictures (landscapes) according to the height of the picture.

(From Fechner's *Kollektivmasslehre.*)

Fechner had the measurements of the height and breadth of thousands of pictures taken. Fig. 21 shows the distribution of landscapes according to their height. The height of greatest frequency was 35 cm. (more than 250 times). The distribution is extraordinarily regular and clearly asymmetrical. The same applies to the genre pictures (Fig. 22). This example shows that the most complicated psychological processes take place in accordance to certain laws.

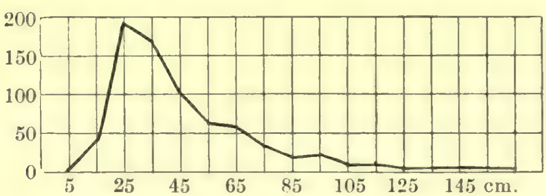


FIG. 22.—Distribution of 775 pictures (genre) according to the breadth of the picture.

(From Fechner's *Kollektivmasslehre.*)

Here we are dealing with very involved æsthetical values.

In Fig. 23 we have obviously a curve of two maxima, similar to that in Fig. 19. Without knowing anything further, we can conclude that it does not deal with a

simple collective object, but that there must be two classes or species present. And this is really the case. I tested my capacity for addition during an uninterrupted period of six hours. The real purpose of the experiment was to measure the progress of fatigue in mental work. The distribution curve would presumably have been a regular asymmetrical one with a maximum at about 160, except for the fact that certain irregularities hindered the progress of fatigue. After the fourth hour, the pain in the hand that was copying down the figures became so acute, that I instinctively let my hand slip down and struck it against

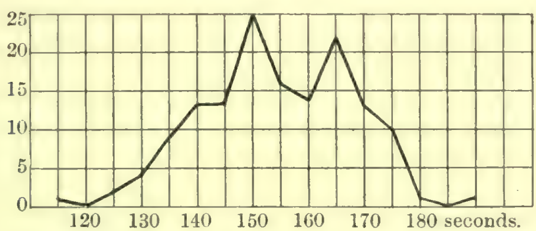


FIG. 23.—Distribution curve with two summits for addition for six hours. (250 additions in 115, 120 . . . 190 seconds.)

my knee. Owing to this massage, some of the fatigue-substance in the hand was no doubt got rid of, and my production rose to 250 additions in 150 seconds, whereas before 160–170 seconds were needed for the same number of additions. Owing to this reason, 150 was the point of greatest frequency; it appeared twenty-five times, and thus formed a second maximum.

This example proves further that it is not allowable to group together work done in different stages of fatigue. Only the figures obtained during the same stage of fatigue (or of practice, &c.) can be classed together to give a middle value. Therefore a psychological investigation must as far as possible always be conducted at the same hour of the day; all irregularities (such as indulgence in

alcohol or tobacco, &c.) must be as far as possible excluded; in short, everything possible must be done to obtain processes of consciousness of the same quality or class.

It is, of course, also obvious here, that only a great number of experiments will lead to sound conclusions.

IV. MEASUREMENTS IN CHILD PSYCHOLOGY AND PEDAGOGY

Child psychology and pedagogy, as well as the anthropology of the child, deal with the development of the human being. The anthropology of the child and child psychology investigate the natural development of the human body and mind, whereas pedagogy takes into account the changes that occur owing to a systematic influencing of the natural development of the whole being. From what has been said above, it is obvious that the objects of investigation of the three sciences mentioned must be dealt with mathematically as collective objects. One further point requires special emphasis. To explain this point, let us take an example out of anthropology.

1. The Change in Asymmetry through Natural Growth

In Fig. 24 in the measurements of the height of the 12- to 13-year-old Freiburg school-girls, we have an extraordinarily even and almost absolutely symmetrical distribution. The asymmetry of biological distribution is sometimes very small, and there are exceptional cases of absolute symmetry.

In the thirteenth year a period of increased growth sets in, as is normally the case. In the second curve

(age 13–14) the asymmetry appears, but is very indefinite; in the third curve (age 14–15) it is very appreciable. This can be easily explained. Only if all the children increased by exactly the same amount each year, would the symmetrical curve of the 12- to 13-year children move towards the right along the abscissa without changing its form. But, of course, certain groups of children—*e.g.* those who up till now were backward in development—grow at a

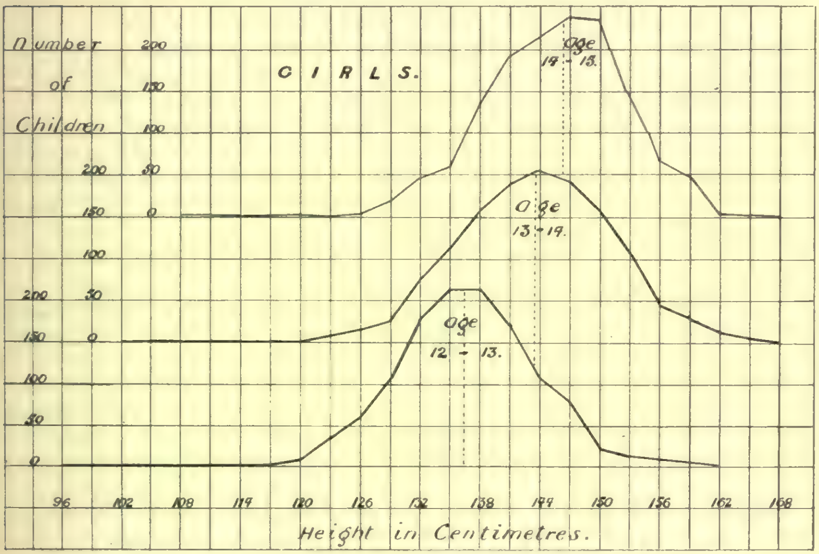


FIG. 24.—Distribution curve of the height of Freiberg elementary school-children.

(From Geissler and Uhlitzsch, *Zeitschrift des Sächs. Statist. Bureaus*, 1888.)

different speed than the rest. Hence at a period of increased growth an asymmetrical shifting of the curve must take place. This appears very clearly if we arrange the three curves above each other (Fig. 25). We may therefore take it for granted that in general the asymmetry of the distribution will be comparatively great during periods of increased growth. The first curve also

helps to strengthen our statement. Girls of 12–13 years show the smallest increase in height during the whole school-period, and their curve shows the least asymmetry.

2. The Expansion of Distribution through Natural Growth

In Fig. 26 we see the distribution of the heights of over a thousand children, first at 6 years old (admittance to school), and then at the end of their tenth year. The

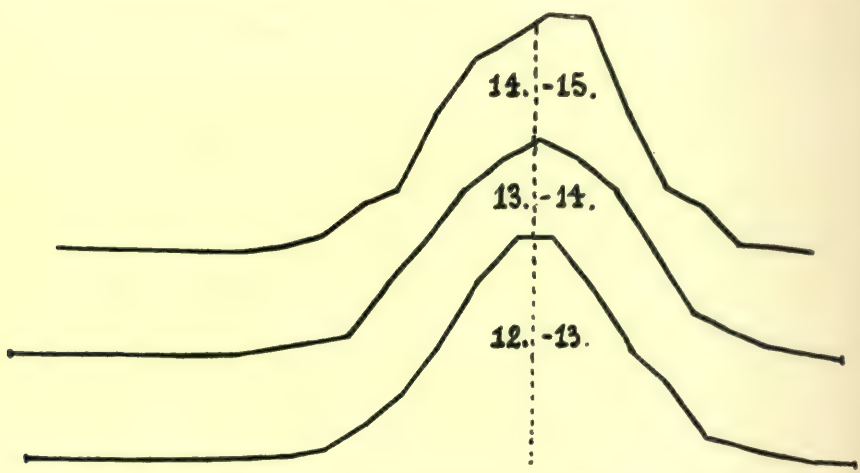
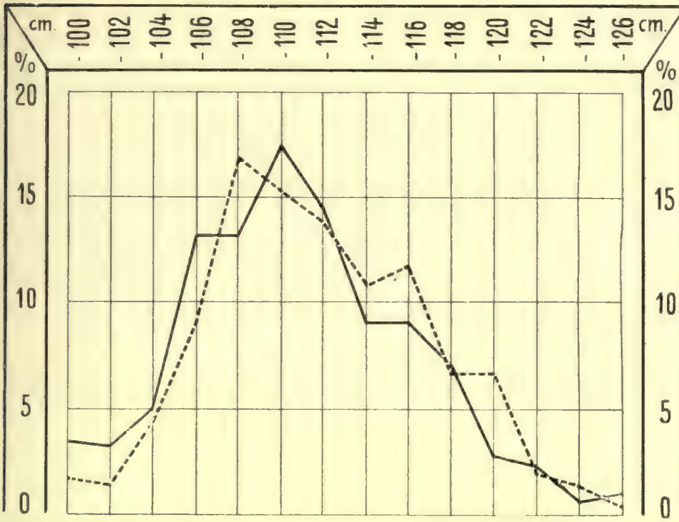


FIG. 25.—Height of Freiberg elementary school-children from age 12–15.

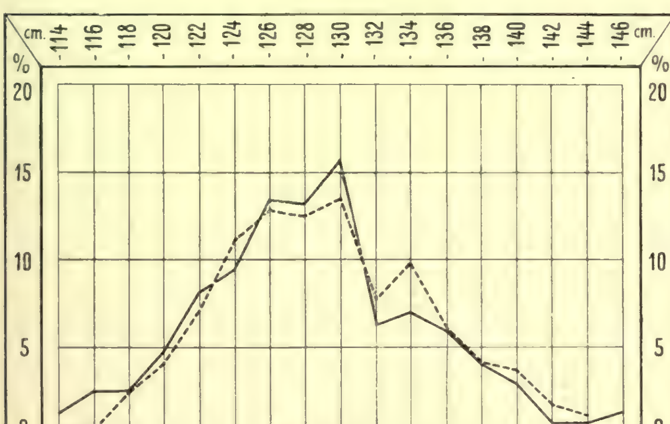
asymmetry of the curve tends first of all towards the left; later it has shifted towards the right.

Besides this, we note that the distribution has expanded—has become much broader. With the children of 6 years it was 26 cm. (100 to 126 cm.), with the others it has increased to 32 cm. (114 to 146 cm.) This expansion of distribution is a characteristic of normal growth. It also brings out the fact that the development of all organisms is a process of progressive differentiation.



...... Boys. —— Girls.

1016 children. Beginning of sixth year.



...... Boys. —— Girls.

1014 children. End of tenth year.

FIG. 26.—Growth in height of 1000 children from age 6–10.

(From Quirsfeld, *Zeitschrift für Schulgesundheitspflege*, 1905. Voss.)

3. The Change in Asymmetry and the Expansion of Distribution through Pedagogical Influence

If pedagogy wishes to bring its influences to bear upon the child, it must follow closely the natural development of the human being. It must not set up abnormal conditions of development. It must choose according to its special plan and bring into use the natural conditions of development, and thus give each individual an opportunity to educate himself according to his faculties. This being the case, we are led to expect, that through reasonable pedagogical influences essentially the same characteristics will appear as in the natural progress of development, only that here the form may be a little different and the rate a little quicker. We should be able, therefore, to find here also the same shifting of asymmetry and the same expansion of distribution as we found before.

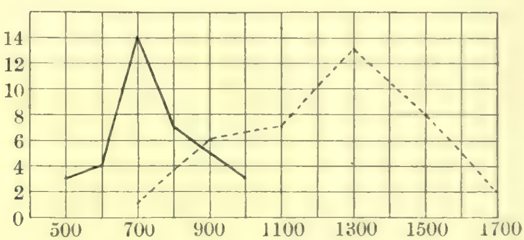


Fig. 27.—Distribution curve of the ability of a school-class in addition before and after systematical practice.

The first curve in Fig. 27 shows the distribution of the capacity for adding digits of Leipsic school-girls of 12–13 years. In every 25 minutes, up to 500 correct results were obtained by three pupils, up to 600 by four, and so on. (This can be easily read off from the curve.) I then gave the class several half-hours of systematical practice in this work. The dotted curve shows the result.

Our expectations have been realised. We observe first of all a considerable expansion in the distribution—exactly double. At first it extended from 500 to 1000, now from 700 to 1700. If further experiments corroborate this result, we can regard this phenomenon as normal. The demand for absolute uniformity in class-teaching, can, if pushed to the extreme, lead to dangerous consequences. Such a uniformity is very likely possible, as our example from biology in Fig. 18 shows, but only by creating abnormal conditions of life—only by the deprivation of "the natural light." The uniformity arises there in the following manner—not that the normal type develops further (the middle value remains 5), but that the more richly endowed individuals, because of insufficient development, come down to the normal type. If, however, the natural process is one of increasing differentiation with increasing age, then as a necessary consequence we must demand a greater differentiation in education with the increase in age. The introduction of special classes for specially gifted pupils in the Mannheimer system shows in Germany the first beginnings of carrying out this demand in the elementary schools of the country.

The change in asymmetry can also be clearly seen. If this change were always to occur as in our example,[1] namely, to the right, it would follow that a comparatively large number of the pupils in the upper classes ought to be put into special classes for backward pupils, and only a small number in such classes for specially gifted ones. The density value 1300 lies nearer the maximum 1700 than the minimum 700 does, whereas in the first curve the density value 700 lies nearer the minimum 500.

We have maintained that the mathematical treatment of pedagogical problems should always follow the principles of the theory of collective objects. An asym-

[1] Other experiments on this problem are unknown to the author.

metrical distribution according to the law of error should therefore result in all cases where the freedom of distribution has not been artificially hindered. Let me give another example of this.

In Germany, according to strict school regulations, each age (say the girls of 13–14 years) is fixed to a special class. Some remain in the same class one or more years. We would obtain as a distribution curve of the girls of 13 years, a curve that is very one-sided, with a steep

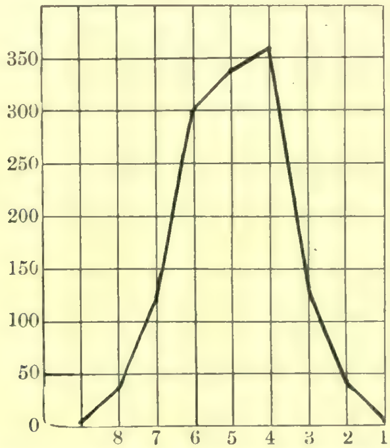


FIG. 28.—Distribution of 1334 thirteen-year-old girls of St. Louis in grades.

(From Townsend Porter, *Zeitschrift für Ethnologie*, 1893.)

maximum in the first (highest) class, then it would fall very quickly down to the second, third, and fourth classes. If, however, there was natural freedom of distribution, if the pupils were advanced according to their capacities, we ought to get a distribution that resembles Gauss's law.

This is actually the case in America, and we see in Fig. 28 the distribution of 1334 school-girls of 13 years in St. Louis.[1]

Six of the pupils were in the first class, the lowest

[1] Townsend Porter.

grade, four in the second, and so on, as in the following table :—

Class.	No. of Pupils (age 13).
I.	6
II.	41
III.	129
IV.	363
V.	331
VI.	300
VII.	121
VIII.	37
High School	6
Total	1334

The curve gives the picture of an absolutely regular asymmetrical distribution. The nearer such a distribution (with a sufficient number of individual observations) approaches Gauss's law, the more certain can we be that the distribution is a natural one.[1]

Since the asymmetry of distribution is an essential characteristic in child psychology and pedagogy, it must never be neglected in statistics.

[1] Thorndike gives a great number of examples of distribution for various capabilities of school-children. E. Thorndike, *Educational Psychology.* Lemcke & Büchner, New York, 1903.

CHAPTER II

THE MEASUREMENT OF SENSATION

I. THE METHODS OF PSYCHICAL MEASUREMENT

1. The Possibility of exact Measurement in Child Psychology and Pedagogy

Each teacher gives marks—very likely for the attentiveness or industry of the pupil. He thereby arranges the value of a psychical accomplishment according to a certain measure, and in doing this he serves as a proof for the naive notion that the possibility of measuring psychical processes is a thing to be taken for granted. Such measurements have two great drawbacks: Firstly, they are extremely inaccurate; and secondly, the measurements or marks assigned by different teachers have no common basis for comparison;—they are purely individual, not general. For this reason, the tremendous amount of work in assigning marks which many thousands of teachers are doomed to carry out at the end of every school year—all this work will never advance scientific pedagogy by one step.

If, however, we could get figures which were accurate, and which we could compare with each other, pedagogy could then begin to solve problems, which at present cannot be attempted. If, for example, we could find a method by which each teacher in the same manner could determine accurately in figures the memory-power of his pupils, we could measure and compare the memory-power at all ages of growth. If the same measurements

were carried out every 50 or 100 years, we could tell whether in following generations the memory was better or worse, just as we can at the present day determine whether our athletes are stronger or speedier than the champions of the old Greek athletic contests. Yes, we could then prove the value of any educational reform, say the introduction of special classes, in regard to the development of memory, if before and after the introduction a sufficient number of measurements were taken.

We must therefore discuss this extremely important question of the possibility of exact measurement of psychological values.[1]

In physics we make a distinction between direct and indirect measurement. It is, for example, a direct measurement, when we determine the length of a rod by laying a yard-stick by the side of it and reading off the length in question. We are here measuring lengths with lengths. It is otherwise when we determine the temperature. We possess no direct heat "yard." Here we must measure the heat by the expansion which takes place in a mercury column—*i.e.* quite a different quantity. For this reason, we cannot say that to-day it is "once as warm," or "half as warm" as yesterday; we must say "it is warmer or colder." Now, it is further quite obvious that we cannot directly measure psychological values—for example, sensations. That would presuppose that we possessed a graduated sensation scale, or sensation "yard," which we could keep by us and at any time measure any sensation we chose.

An indirect measurement is, however, possible. I can measure the sensations by means of the stimuli which produce them. I can say, for example, about a

[1] *Cf.* G. F. Lipps, *Die psychischen Massmethoden;* G. E. Müller, *Die Gesichtspunkte und die Tatsachen der psychologischen Methodik;* O. Külpe, *Grundriss der Psychologie;* Wundt, *Grundzüge der physiologischen Psychologie*, Band I.

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sensation of light, "this is a sensation which arises when I see one candle burning," and "this is a sensation which arises in me when I see 1000 candles burning." But I have really gained nothing by this. If I compare the two sensations, the most that I can say is, that the one is greater than the other. I do not know whether it is 1000 times or only twice or perhaps 10,000 times as great as the other. We cannot speak here of a real measurement.

Again, a comparison between different individuals is absolutely impossible by such a measurement, and in pedagogy such a comparison is exactly what we want to achieve. We only know that in observer A. as well as in observer B. the sensation caused by 1000 candles is greater than that caused by one candle; but we can say nothing definite as to whether the sensation caused by one candle in A. is the same as or greater than that in B. We shall soon see, however, that there are cases where a comparison between individuals is possible.

2. The Range of Application of the Methods of Psychical Measurement

(a) *The Determination of Stimuli Thresholds or Limens.*

In special cases it is possible to overcome the difficulties described in the previous paragraph. I might ask, What is the smallest stimulus—*e.g.* the smallest amount of light—that is just sufficient to cause a sensation in observer A. or B.? This stimulus is called the stimulus threshold. I can also determine the terminal stimulus—*i.e.* I can ask, With how many candles have A. or B. the strongest sensation of light, so that the addition of more burning candles would cause no change or intensification in their sensation? The investigation of terminal stimuli is for practical reasons (especially with children) not to be recommended,

because, owing to the effects of very strong light or very high tones, damage may be done to the sense organs. The stimulus threshold can, however, be determined for adults and children, and it leads to figures for comparison. If one child has a light sensation from a very small degree of brightness, I can say that it possesses a greater sensitivity for light than another child who requires a greater degree of brightness before a light sensation arises.

The colour-mixer (Figs. 29 and 30) [1] is used to deter-

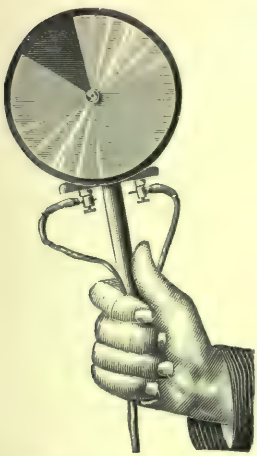


FIG. 29.—Colour mixer.

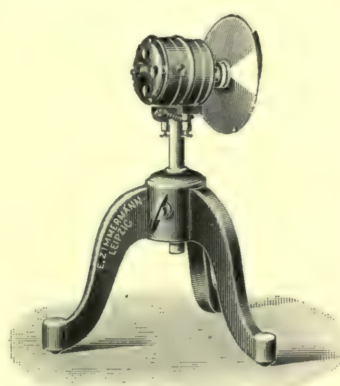


FIG. 30.—Colour mixer on stand.

mine the stimulus thresholds for the intensity (brightness) or for the quality (colour-tone or saturation) of a light sensation. The apparatus, the colour-mixer, can be set in motion by a small electric-motor, driven by an accumulator, or by three or four dry batteries. For individual experiments, it stands securely on the table (Fig. 30). For demonstration purposes, the other apparatus (Fig. 29) is preferable, as it may be carried about in the hand during rotation. Fig. 31 shows a child sitting before the apparatus during an experiment on the stimulus threshold.

[1] Pictures taken from the catalogue of Zimmerman, Leipzig.

On the colour-mixer there is a large grey disc, the front view of which is given in Fig. 32. It has a radial slit that extends to the centre of the grey disc, so that a smaller coloured disc (say red) can be inserted. If this

FIG. 31.—Investigation of the stimulus threshold for colours.

smaller disc only projects by a few degrees, the whole disc, even the inner circle, appears during rotation quite grey. Now, when I have determined how many degrees of red must be added in order that a trace of red may be just noticed in the inner circle, I have fixed the stimulus

threshold for the sensation of red in question. (Fig. 31

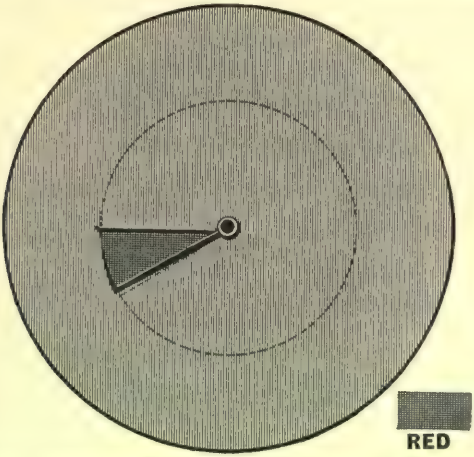


FIG. 32.—Colour disc for investigating the stimulus threshold.

shows also how the degrees are measured off on the back of the disc of the colour-mixer.)

(b) *The Determination of Difference Thresholds.*

Fig. 33 shows two colour-discs. The first is divided into 180° blue and 180° grey. During rotation a certain

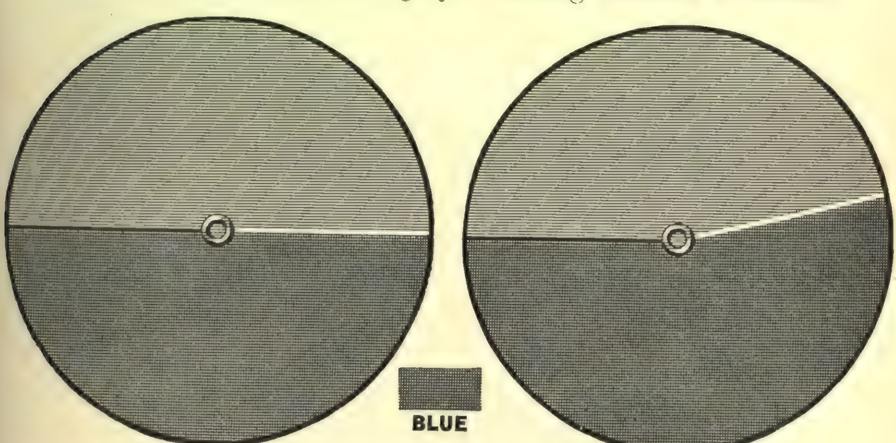


FIG. 33.—Colour discs for investigating the difference sensitivity.

blue will result. The second disc shows the addition of more blue. By these means I can investigate how many more degrees of blue must be added in order to give a second blue colour that is just noticeably stronger than the first. This value is a measure for the degree of sensitivity, or the difference sensitivity.

The determination of the difference sensitivity is much more important than that of the stimulus threshold. If I wished to investigate whether a child is musical or not, I could determine the stimulus threshold by finding out how many vibrations (sixteen or more) per second a tone must make, before it is recognised as a tone. But it would be of much greater importance to determine how many vibrations must be added to a tone about the middle of the scale, in order that a second tone be distinguished from the first. Musical talent will in most cases show itself clearly in the difference sensitivity.

(c) *The Determination of Stimuli that appear Equivalent.*

In the methods of investigation just described, we have been changing the stimulus, until a definite change in the sensation took place. In the first case (stimulus threshold) until a sensation appeared; in the second (difference threshold) until we arrived at a sensation that was felt to be different from the original sensation.

I could now ask the opposite question: Under what conditions do two different stimuli give rise to two sensations, which in one particular at least appear the same? They can never appear absolutely the same. For even if we are dealing with two lines, which, according to my judgment, are equally long, yet the two sensations are in so far different as the one line appears above or below, right or left of the other, &c. Therefore, I can only say

that two sensations are the same in one particular. In other words: two different stimuli can call forth sensations, which in one particular seem equal or equivalent.

For example (Fig. 34), I can compare a green disc (*a*) with a grey one (*b*) The grey is obtained by a certain mixture of white and black. I now change the green by increasing the degrees of white, until the green and grey discs appear equally bright. I thus obtain in

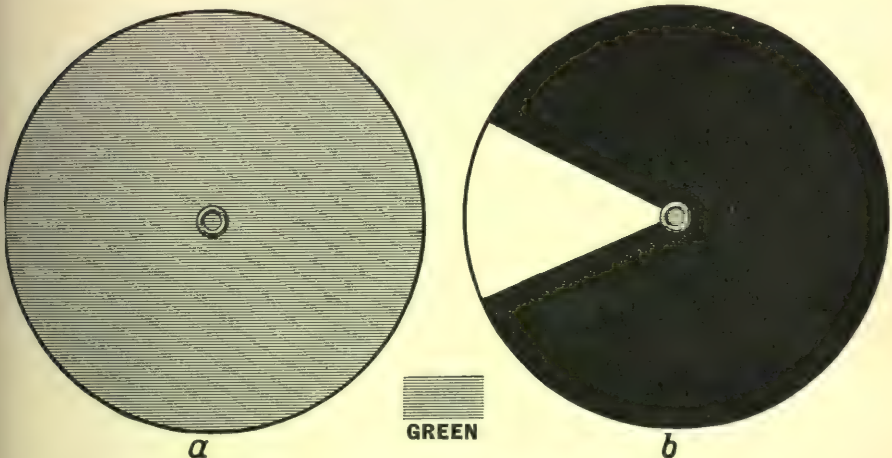


FIG. 34.—Colour discs for investigating stimuli that appear equivalent. (Colour and brightness.)

regard to one particular, viz. brightness, equivalence or sameness.

(d) *The Determination of Differences that appear Equivalent.*

A similar case is seen in Fig. 35. By rotation of the whole disc, we get in the middle a black circle, outside a white strip, and between the two a grey one. I can now set myself the problem to change the grey strip in the middle until, according to my judgment, it represents a

brightness of grey that lies exactly in the middle between the white and black. According to my sensation, then, the difference between the grey, I have

FIG. 35.—Colour disc for investigating differences that appear equivalent.

chosen, and the black is exactly equivalent to the difference between the same grey and the white. This is an example of determining differences that appear equivalent.

In child psychology and pedagogy we would do best to limit our investigations for the sake of simplicity to the determination of stimulus and difference thresholds.

3. The Three Methods of Psychical Measurement

(a) *The Method of Continuous Variation.*

To determine more accurately the stimulus threshold for colour-tones, we must make use of a colour-mixer, on which the red slit can be increased or decreased by

means of a screw during the rotation of the whole disc.[1]

The first question to answer is: How shall this increase or decrease of the red slit take place? The simplest method is to leave this to the observer. He is permitted to turn the screw this way and that, until he arrives at the place where he can say that the middle circle is just noticeably red. This is called the method of continuous variation, because the stimulus is varied continuously this way or that.

The disadvantages of this method are, of course, obvious. We shall obtain quite different results according as the observer changes quickly this way or that, or according as he makes the changes slowly and calmly. And worst of all we cannot tell, out of the figures obtained, how the observer has set about his task. One may always start with a great deal of red, another with no red, and so on. The figures can tell us nothing of this.

So this method of continuous variation is the most unmethodical of the psychical methods of measurement. It cannot be used in investigations in child psychology.

(b) *The Method of Limits.*[2]

Investigation of the Stimulus Threshold according to the Method of Limits.

The colour-mixer contained a large grey disc and a small green one. I turned the screw so that 10° of the green could be seen. A girl of 9, with whom I was experimenting, gave the judgment, "All grey," when the disc was set in rotation. During the

[1] Like Prof. Marbe's apparatus.

[2] So Kraepelin. Wundt calls it the method of minimal changes.

rotation I then turned on to 11° green. Her judgment remained the same. At 12°, 13°, 14°, 15°, 16°, still the same judgment. At 17° came the statement, "In the middle there is some green." I noted 17 as the threshold in the ascending series.

I now turned the green up to 19°, then up to 22°, then to 25°, until I noticed that the sensation of green was quite perceptible, so that no mistake was any longer possible. I then began a descending series. From 25° I descended every time by one degree. At 17 came the first judgment, "all grey."

I repeated the descending and ascending series three times more, and obtained the following figures :—

	Ascending.	Descending.
1st Experiment	17°	17°
2nd "	16°	16°
3rd "	16°	17°
4th "	18°	17°

The first row shows us when the sensation of green just appears, and the second when it just disappears. We presuppose that the stimulus threshold will lie between the threshold of each series, and therefore we can take the arithmetical mean of the two. In our example these were by chance the same, but this is mostly not the case. The arithmetical mean is 16·75°. From this we can reckon the error of each observation :—

	Ascending.	Descending.
1st Experiment	·25°	·25°
2nd "	·75°	·75°
3rd "	·75°	·25°
4th "	1·25°	·25°
Total	3·00°	1·50°

Taking all experiments together, we get in eight experiments a total error of 4·50°. Our average error (or

mean variation) will then be, according to our formula on page 23 :—

$$E_m = \frac{\Sigma\Delta}{n} = \frac{4 \cdot 5}{8} = \cdot 5625^\circ$$

The average error from the ascending and descending series differs very largely. This is certainly due to the small number of experiments made.

If a very great number of experiments have been made, it is possible to treat the figures of the ascending and descending process separately. We would also then take as our middle value, not the arithmetical mean, but the value of greatest frequency, the density value. Such a treatment of the figures would not lead to more fruitful results, and therefore, the simple treatment we have described is to be recommended for pedagogical purposes, only it is better to calculate the average error or mean variation according to the following formula, also given on page 23 :—

$$E_m = \sqrt{\frac{\Sigma\Delta^2}{n-1}}$$

This would give in our case :—

$$E_m = \sqrt{\frac{\cdot 25^2 + \cdot 75^2 + \cdot 75^2 + 1 \cdot 25^2 + \cdot 25^2 + \cdot 75^2 + \cdot 25^2 + \cdot 25^2}{7}} = \sqrt{\frac{1}{2}} = \cdot 7$$

The probable error of the single observation would then be :—

$$PE = \cdot 6745 \sqrt{\frac{\Sigma\Delta^2}{n-1}} = \cdot 6745 \times \cdot 7 = \cdot 47$$

If the number of the experiments is not given, one must never omit to give the probable error of the arithmetical mean, which, according to the formula, in our case would be :—

$$PE_m = \frac{PE}{\sqrt{n}} = \frac{\cdot 47}{\sqrt{8}} = \cdot 17$$

For all pedagogical purposes it is sufficient to give the arithmetical mean, the mean variation $\left(\sqrt{\frac{\Sigma\Delta^2}{n-1}}\right)$, and the probable error of the arithmetical mean $\left(\frac{\cdot 6745}{\sqrt{n}}\sqrt{\frac{\Sigma\Delta^2}{n-1}}\right)$.

Investigation of the Difference Threshold according to the Method of Limits.

This investigation is conducted in a similar manner to the above. I compare two colour-discs (Fig. 33), and begin from the point where on the second disc there is so much more blue that the difference is clearly perceptible. I then descend, a degree at a time, until both discs appear the same. I have thus fixed the difference threshold in the descending process. I then ascend, until a difference is just perceptible. And so I fix the point of just noticeable difference in the ascending process. I can now repeat these experiments and calculate the arithmetical mean, the mean variation and the probable error, exactly the same as in finding the stimulus threshold. But this is only half the work. For I have obviously only fixed the upper difference threshold. (DL^u.) [1] To determine the lower difference threshold (DL_l), I must start by decreasing the blue of the second disc so much that it will appear much less blue than the first one. And now I must ascend until both blues appear equal, and so on as in determining the upper difference threshold. Of the upper and lower threshold I then take the mean and obtain the mean threshold (DL_m).

For the sake of simplicity, the two methods are generally combined. We descend from a noticeably larger stimulus until the sensations appear equivalent (the just unnoticeable difference of DL^u), then descend a little further until

[1] DL = difference limen.

the second stimulus seems just a little smaller (just noticeable difference of DL_l). Then we descend still further until the difference is very noticeable. Now we ascend until both stimuli appear the same (just unnoticeable difference of DL_l), and then still further until the second appears greater (just noticeable difference of DL^u). After several repetitions of the whole process, I reckon out first the upper difference threshold by taking the arithmetical mean, the mean variation, and the probable error of all the just noticeable and just unnoticeable differences of the upper threshold (exactly as in fixing the stimulus threshold). I then repeat the same calculation for the just noticeable and just unnoticeable differences of the lower threshold. Of these two threshold values (DL^u and DL_l), I take the mean and so obtain the mean difference threshold (DL_m), or for shortness the difference threshold (DL).

(c) *The Method of Constant Changes.*

This method gives the most accurate results. Here, just as in the method of limits, we work with a number of fixed graduated changes. Only here these gradations are not presented in their natural sequence, but are first thoroughly mixed up together. The observer is called on to give one of the three judgments—greater, smaller, or equal.

The way in which we should deal with the results obtained by this method, has led to long and tedious discussions. Great difference of opinion has arisen as to how we should classify the "equal" judgments. As it is undesirable to repeat all this discussion in a book on practical child psychology and pedagogy, we shall not recommend the use of this method. It is still in an unsettled condition. Experiments according to this

method also make a great call upon the staying-power of the observer.

We therefore recommend the method of limits as the best for experiments in child psychology and pedagogy.

By using the three methods of psychical measurement in the four departments of sensation—measurement (see pp. 50–55), we obtain twelve different cases. But since we recommend in child psychology only the method of limits, and this only to be applied to investigate the stimulus and difference thresholds, there remain for us the two following cases: investigation of the stimulus threshold according to the method of limits, and of the difference threshold according to the method of limits. We have given a detailed description of both.

4. The Meaning of the Figures Obtained

In our experiment on the 9-year-old child, we obtained the following figures :—

Sensitivity for the saturation of a green colour . .	16·75°
Mean variation	·56°
Probable error of the difference threshold . . .	·17°

(a) *Sensitivity.*

What do these figures mean? As they stand there alone they mean nothing. The figure 17 (for sensitivity) tells me simply that I must mix 17° of green with 343° of grey in order to get a green which is just noticeable. But this figure increases at once in importance, as soon as I have other figures for comparison, which were obtained under exactly the same conditions.

I give once again the separate results of the experiment with the child, and for comparison the results of the same experiment with a woman of 60. As the wife of a

drawing-teacher and the mother of an artist, she would certainly have had experience in colours.

	Frida L. (9 years).		Mrs. N. (60 years).	
	Ascending.	Descending.	Ascending.	Descending.
1st Experiment	17°	17°	25°	29°
2nd "	16°	16°	27°	30°
3rd "	16°	17°	26°	29°
4th "	18°	17°	28°	29°

We can see here clearly that the 9-year-old child is superior to the woman of 60, not only in sensitivity (17° versus 28°), but also in regard to the steadiness of her judgments. At first I feared that the child was only guessing, *i.e.* that she always said "green" after a certain number of single experiments had been made. Therefore I undertook a new set of experiments with the child in which four colours were used. I employed the so-called "method without knowledge." The child did not know which of the colours would appear. The colour-mixer was covered, set in rotation, then uncovered, and only then did the colour gradually appear. Here, of course, the ascending method alone could be used. I experimented under exactly the same conditions on the child, on Mrs. N., on Mrs. L., the mother of the child (40 years old), and on Mr. K. (drawing-teacher, about 40 years old). I obtained the following results :—

	Frida L. (9).	Mrs. L. (40).	Mrs. N. (60).	Mr. K. (40).
Purple	10°	9°	18°	5°
Blue	10°	11°	17°	5°
Red	7°	7°	13°	8°
Green	10°	10°	18°	8°

Note first of all, that the stimulus threshold of all

observers by this method without previous knowledge is not, as one would expect, larger; it is smaller. Perhaps this arises from the fact that by the other method the constant appearance of the same colour gradually creates a slight insensitiveness for that colour, and also gives rise to a certain uncertainty in judgment. A comparison of the sensitivity of the child with that of Mrs. N. shows that the relation between the two has remained the same; before it was 17 : 28; now it is 9 : 16. Also in this experiment the child shows an extraordinary evenness in its judgments. (The value 7° in red would seem to arise from some constant error, because the sensitivity for red for all observers, except Mr. K., shows very low values. As a matter of fact, after a careful test, it was found that the red did not correspond in brightness to the green employed.)

This experiment with the child shows with what good results the exactest methods of psychology can be used. Wundt has repeatedly written against the use of experimental methods in child psychology, and many educationalists have misunderstood his words. He obviously means them to apply to the psychology of childhood, *i.e.* to the first few years of the child's life.[1] He has clearly stated his belief in the use of experimental methods with school-children. Now if we do decide to experiment with school-children, then we ought to take care to use the exactest methods possible. In investigating the colour-sensitivity of school-children the "naming" method has been used, *i.e.* the child had to name slips of colour of different colour-tone; or the "covering" method, *i.e.* the child had to cover coloured slips with slips of the same colour. Little can be achieved with these rough-and-ready methods. If one is reminded that the colour-sensitivity of the Japanese mouse has been fixed at $\frac{1}{10}$, it would almost suggest the idea that Japanese mice are

[1] Wundt, *Outlines of Psychology*, p. 336. Leipzig, 1907.

more trustworthy and more interesting observers than our school-children. Fig. 36 shows how in animal psychology such investigations are made.

It must be remembered that our experiments deal with the determination of the sensitivity for colour-saturation and not for colour-tones. To determine this latter, one colour must be changed gradually in the direction of the next colour on the spectrum, until a change has been observed. By this means we arrive at the difference sensitivity for the colour in question.

In our experiment the great similarity between the figures for the mother and child is very striking. Again our experiment raises the question as to whether the colour-sensitivity of children, as is generally supposed, is really very much less than that of adults. Of course we dare not generalise from our particular case. If it were not so, that the colour-sensitivity of children is less, then we would have to suppose that it is in the naming of colours that children are weaker. Pedagogy would then have to reckon with this fact, and would have to cultivate the colour-sense of children more than it has up till now, even with the youngest children.

Comparisons between adults and children have presumably very often led to false conclusions, because the figures obtained from school-children and those obtained in laboratories from students and professors have been without any allowance compared. Now the school-children generally belong to the middle or lower classes, and the professors and students to the upper class. To obtain valid comparisons we ought to take individuals out of the same class. It would be very useful to experiment also with the parents of the children in question. This would be of great interest in regard to children of exceptional talent, since it might lead to important results for the theory of heredity. Many a country teacher,

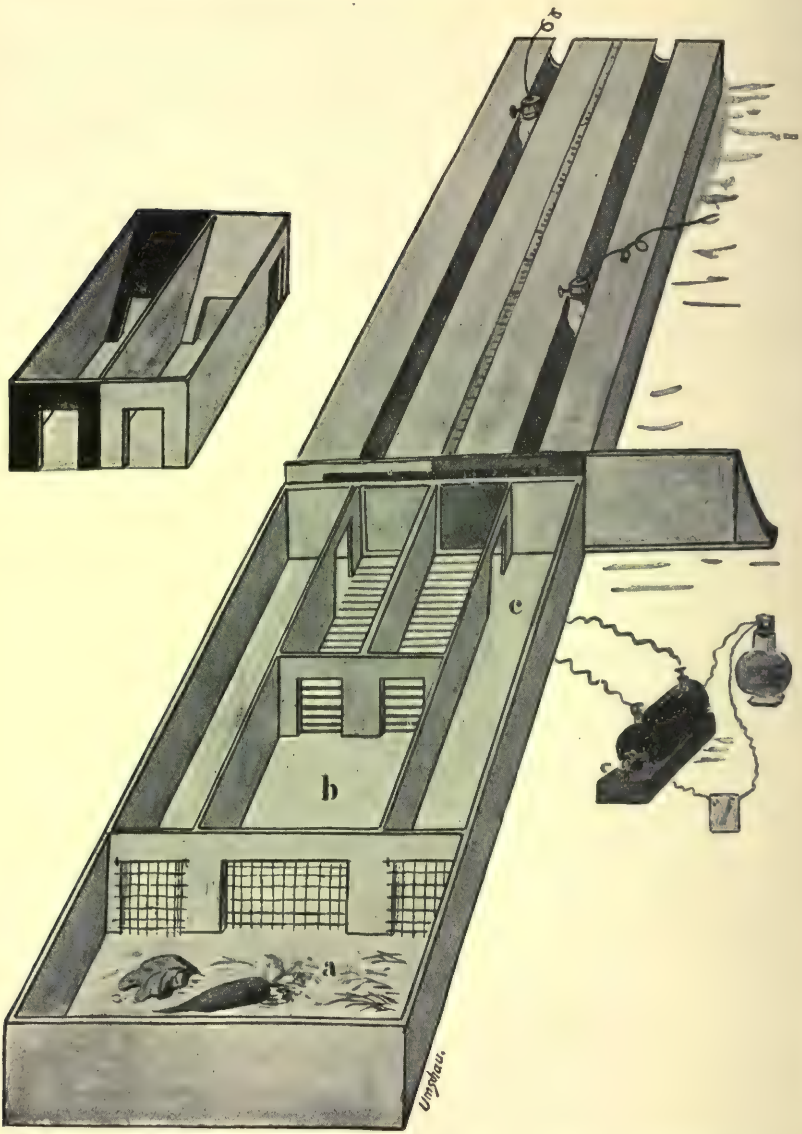


FIG. 36.—Yerkes' arrangement for determining the power of discrimination of colours in mice. One compartment is illuminated red, the other green.

(From Claparède, *Umschau*, 1908, Nr. 26.)

under whose hands two or three generations of the same family pass, might obtain very important scientific results, if he conducted year after year such simple experiments on the children and parents of the same families. To arrive at striking results quickly is not so easy for experimental psychology. More important is conscientious work done year after year, that slowly but surely helps to settle the problems we are faced with.

If investigations on the colour-sensitivity of children had been made,[1] we might, for example, be able to say that the colour-sensitivity among boys in the sixth class was equal to that of girls in the eighth class. Further, if the colour and form sense had thus been investigated, we would obtain great help in reforming our methods of teaching drawing. Many observers maintain that there is such a difference between boys and girls, and yet, in most schools, boys and girls are taught in exactly the same way.

Many will say that it is absurd labour to carry out 100 or more experiments merely to find out one single child's sensitivity for one single colour. But we must remember that the methods of exact science are always slow and tedious. Think of the scientists, who spent years of work investigating the qualities of the cathode rays, without at first arriving at results worthy of note. Then all of a sudden came the wonderful discovery of Röntgen rays and of radium with all its marvellous qualities.

If it is considered worth while counting the number of filaments in 17,000 dandelion flowers; if a physiologist[2] is not frightened of carrying out 60,000 experiments on

[1] Ll. W. Jones, "Untersuchungen über die Reizschwelle für Farbensättigung bei Kindern," *Veröffentlichungen des Instituts für exp. Pädagogik und Psychologie,* Bd. II. Leipzig, 1911. These experiments appeared after the German edition was published.—*Translator.*

[2] Camerer, *Zeitschrift für Biologie,* 1881, XVII., "Versuche über den Raumsinn der Haut bei Kindern."

his two children in order to fix the fineness of the space threshold of the sense of touch, then we ought not in experimental pedagogy to shrink from experiments that demand a great amount of time.

(b) *The Mean Variation.*

The mean variation or the distribution of the figures is clearly a measure for the certainty and trustworthiness of the observer, and for the evenness of attention during the experiments. It can in some cases be quite independent of the degree of sensitivity. An observer with a very indifferent threshold may yet give his judgments with extraordinary evenness. The mean variation, therefore, gives us information about a more general and a more important characteristic of the observer than the stimulus threshold, which we set out to investigate. It can often become of more importance than the latter. We should, therefore, never omit to calculate and mention the mean variation.

Our nine-year-old girl showed a very remarkable constancy in her judgments. The mean variation only amounted to ·56, while for Mrs. N., as we can see at a glance, it is much greater.

The certainty of the child's judgment was also shown in the fact that she only once (in the method without previous knowledge) gave a wrong judgment. She said at 9° green—" Blue or green." At 10° green came the judgment, " Green." The colour was really a green that tended towards blue. So this judgment was almost correct. The rest of the judgments came in this way: the girl always saw grey so long as the colour-tones were weak, but as soon as they were strong enough, the right judgment always came at once.

On the other hand, the mother of the child gave many

wrong judgments as long as the colour-tones were weak. The real appearance of the threshold was generally characterised by some such statement, "This time I am quite certain that it is right."

It would be of great importance to investigate systematically this problem of the trustworthiness of school-children. We might find out how it increases or decreases according to age, if there are differences between girls and boys, or if between the different classes or races.

The mean variation in experiments dealing with the determination of the stimulus and difference thresholds would be a great help to the investigation we have suggested.

5. Precautions for the Investigation of Stimulus and Difference Thresholds

Whoever wishes to take up investigations of the kind we have described, must take care to follow strictly quite a number of rules,[1] if he wishes his results to be of any lasting value. We shall mention, briefly, a few of these regulations which bear upon the experiment we have just described—

(*a*) With children the method without previous knowledge should be used. If, however, it is thought necessary to use the method with previous knowledge (in order to obtain a descending series), then care must be taken not always to begin with the same number, for example, sometimes with 25°, sometimes with 23°, and so on. The child must not get the idea that after a certain number of experiments the judgment always changes. He will, perhaps, begin to count, instead of judging each time independently.

[1] *Cf.* G. E. Müller, *Die Gesichtspunkte und die Tatsachen der psychophysischen Methodik.*

(*b*) All results and methods must be so given, that another experimenter may repeat the experiment under exactly the same conditions. The following details are necessary: How far from the apparatus the child sat (in our experiment, 2 metres); the time of day (2 o'clock); the light (*i.e.* artificial light or diffuse daylight or sunshine, &c.). The quality of the colours used must be exactly determined according to their position on the spectrum. For the isolated experimenter this is not always possible. He will, therefore, do well to obtain coloured paper, which has already been tested in some scientific laboratory.

(*c*) All the conditions of the experiment, except the variable one (in our case the colour-saturation), must be kept constant during the whole period of the experiments. For example, the grey must correspond to all the other colours in regard to brightness. This can be attained by mixing black and white (see Fig. 34) until a grey, that corresponds to the other colours, results. This grey would then be chosen and adhered to for all the experiments.

Further, preliminary experiments must always precede the real series, in order to allow the observer to become accustomed to the apparatus, and to avoid the great change in the figures due to practice. These experiments must never be included in the results. The experiments must not last too long (for children half-an-hour at a time is sufficient), and the single experiment or test must also not last too long. If we know from the preliminary experiments that the threshold lies at about 10°, we must not begin with 1° (this would be useless and make the test too long) but with 4° or 5°.

We have discussed intentionally the determination of thresholds at great length. Child psychology, just like general psychology, must begin by investigating the most

elementary processes. The field for the employment of these psychical methods of measurement is an extraordinarily large one. Stimulus and difference thresholds can be determined for all sensations, and especially for the most important sensations, those of touch, hearing, and sight. We can determine thresholds for the intensity (the brightness of a sight sensation, the strength of a tone, &c.), and for the quality of the sensation (the sensitivity for differences in colours and tones, &c.).

In the same way we can investigate spatial and temporal values. But here we enter into the field of ideas.

II. AN ANALYSIS OF ONE SENSATION

The latest reforms in education have demanded more use of the hand, a greater attention to the sense of touch. If such a problem is to be settled on the basis of psychological investigation, it will be necessary to analyse the sense in question with the experimental means at hand. We must experiment with adults and children of various ages in regard to the different qualities of this sensation. An investigation of the stimulus and difference thresholds might, perhaps, show us what sensations at what ages could be developed by practice. A series of synthetical experiments might then try to describe the co-operation of the different single sensations in complicated work. Such a description would help to settle pedagogical questions of method. Then the results of such experiments in child psychology might lead on to experimental investigation of purely pedagogical problems.

Let us follow this out in regard to sensations of touch. Our description will also be an example of the analysis of a special sense by experimental means.

1. The External Touch Sensations

The simplest observation shows us that in touching an object (say in modelling) we have to do with a complex of sensations. It brings to light at once the two most important components of this complex, the external and the internal touch sensations.

(a) *Contact and Pressure.*

The easiest of the external touch sensations to be isolated are those of contact and pressure. Experimental investigation is here very simple. To determine the stimulus threshold for example, we can place very small weights on the skin. But this would not be the simplest case, as this would stimulate a whole surface, larger or smaller, according to the dimensions of our weights. We must, therefore, begin by stimulating a point (punctiform stimuli). For this purpose we should use the so-called stimulus hair of von Frey (Fig. 37). Or we can make such an apparatus ourselves by fastening a human hair to a piece of wood with wax. If I place this hair on an object it soon bends and exerts a constant pressure, regardless of how much it is bent. This pressure I can determine by pressing the hair upon one of the scales of a balance, and then by putting the appropriate weights (very small, of course) on the other scale. If the hair is too weak, in proportion to a certain desired weight, I simply cut a little off. By this means I can get a series of hairs (say 40 to 60) in a regular graduated scale for an exact experiment.

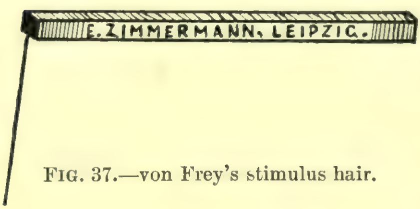


Fig. 37.—von Frey's stimulus hair.

For preliminary experiments and for demonstrations von Frey's hair-æsthesiometer is good (Fig. 38). Here one long hair is fastened in a tube. This is enclosed in a metal case, and by screwing it round I can lengthen or shorten the amount of hair that projects, and thus regulate the pressure. In Fig. 38 at the left is an extra case to protect the hair when not in use.

If I experiment with the finest stimulus hair, and touch the dorsal surface of the hand, I find that there are only certain points where a sensation of pressure arises. These are called pressure spots. At the other points touched, I feel nothing.

The stimulus threshold for pressure on the most sensitive parts of the skin amounts to ·002 gr. on the forehead, and ·005 gr. on the finger-tips. According to an absolute measure this approximates to $\frac{1}{10{,}000}$ erg. From this we see that the sensitivity of the pressure sense is much less than that of hearing (stimulus threshold up to $\frac{1}{10{,}000{,}000}$ erg) and of sight (up to $\frac{1}{100{,}000{,}000}$ erg). On the other hand, we must remember that the surface of touch, because of its great extension, possesses a large number of separate individual qualities. The relative values of the stimulus threshold, the difference

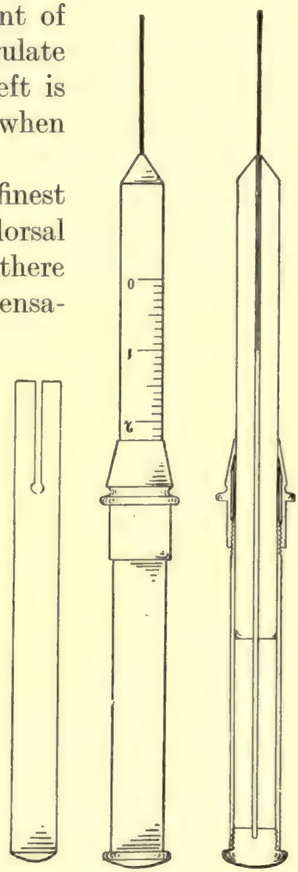


FIG. 38.—von Frey's hair-æsthesiometer.

in sensitivity of the different parts of the body, are of more interest than these absolute values. The following statement, that has been maintained by some authorities, ought to be thoroughly investigated, namely, that the larger cutaneous surfaces (*e.g.* the upper arm) are more sensitive in children than in adults.

The difference threshold for pressure can be best

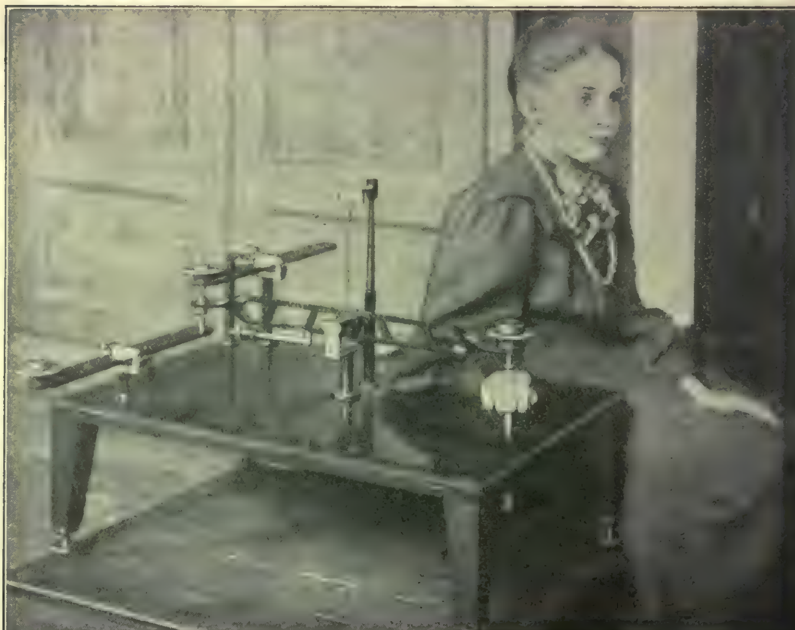


FIG. 39.—Investigation of pressure sensitivity.

(Photographed with Wundt's permission in his institute.)

investigated by means of the kinesimeter of Stratton (Fig. 39). A point resting on the hand is loaded with a normal weight; by means of pressing a lever an immediate increase in weight is brought about. This prevents any falling or jerking which would certainly occur if the weights were each placed on the scales by the hand.

(b) *Pain.*

If I use an æsthesiometer with a very strong hair (*e.g.* a horse hair) I get very different sensations at different places. The investigation is again most easily carried out on the back of the hand. At most places I shall feel only pressure, but at some places a most distinct sensation of pain will arise, which could be described as a prick or a hot piercing sensation. By this method we discover the pain spots on the skin.

(c) *Cold and Heat.*

Just as we went over the skin, touching it with the stimulus hair, so we can go over it with a metal rod, which has a blunt point at each end. With this we also get mostly sensations of pressure. But suddenly we shall come to a point where we have the sensation as if a small piece of ice was touching the skin. We have found a cold spot (Fig. 40). We can mark this with ink, and we find that a cold sensation always arises at this special point. On the wrist a great number of these cold spots are to be found. The slight difference in temperature between the metal and the natural heat of the part of the body under investigation is sufficient to give rise to a sensation of cold. It is best to have a cork holder over that part of the metal rod which is touched by the experimenter, so that it may not be affected by the warmth of the experimenter's hand. If I wish to find warm spots, I warm the metal rod slightly. Warm spots are not so common and do not coincide with the cold spots. Fig. 41 shows the distribution of warm and cold spots on the same part of the arm.

If I heat the rod only slightly above the temperature of the skin, sensations of cold arise at the cold spots.

These are the so-called paradoxical sensations of cold. At the warm spots, with the same rod and the same tem-

FIG. 40.—Investigation of the cold spots of the skin.

perature, I get distinct sensations of warmth. For an accurate investigation of these conditions von Frey's

heat thermometer should be used (Fig. 42). Two rubber tubes are attached to the two metal tubes seen in the figure, and water of a constant temperature is allowed to flow through. The exact temperature at any given time can be read off on the thermometer attached. The point, S, that touches the skin has, therefore, a constant measurable temperature.

Recent investigations have shown that sensations of

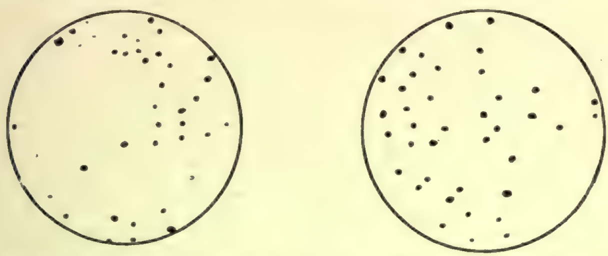


FIG. 41.—Cold and warm spots on the same part of the arm. (From Titchener's *Experimental Psychology.*)

heat (in contradistinction to warmth) represent a distinct species of sensation, which probably arises from a stimulation of warm and cold spots at the same time.

We see, therefore, that even the external touch sensations, which arise say by grasping an object, are most complicated. Physiologically the surface of the skin is like a mosaic of sensitive points, which may be considered as the nerve-endings of different fibres, each class of which transmits a special class of sensations.

From different combinations of these special classes arise those sense-perceptions of roughness, hardness, wetness, &c., which we know from experience, and which, after accurate analysis, ought to be able to be de-

FIG. 42.—von Frey's thermometer-rod.

rived from the primitive elements. For example that the sensation of wetness arises fundamentally from the circumstance of a smooth, cold object moving over a part of the body, can be shown by passing the smooth part of the metal rod we used for cold spots over the back of the hand. The observer, who, of course, must keep his eyes shut during the experiment, generally tries to wipe away "the water."

2. The Internal Touch Sensations

Here the conditions are much more complicated. If I investigate the pressure sensitivity of the skin by placing weights on the hand at rest, I find that the difference sensitivity is about $\frac{1}{3}$, *i.e.* I must add $\frac{1}{3}$ kg. to 1 kg. in order to notice a difference. (With the kinesimeter Stratton lowered it to $\frac{1}{18}$.) If, on the other hand, I raise the weights in comparing them (Fig. 46), the difference sensitivity becomes much greater ($\frac{1}{30}$), and we know from self-observation that here not only pressure sensations but other sensations take part, mainly sensations of position and effort, the fineness of which must be separately investigated.

(a) *Position.*

Sensations of position can be best isolated. They seem mostly to take place in the joints. They can be investigated by means of the kinematometer (Fig. 43). One member of the body (say the arm) is so fastened so that only one joint can move. The length of the movement can be measured off in degrees on the apparatus. The experimenter moves the arm into a certain position

(passive movement), and the observer has to say how far the new position is from the old one. The external touch sensations are not essential to ideas of position. Patients, whose skin is absolutely insensitive, yet possess, with closed eyes, an accurate idea of the position of the

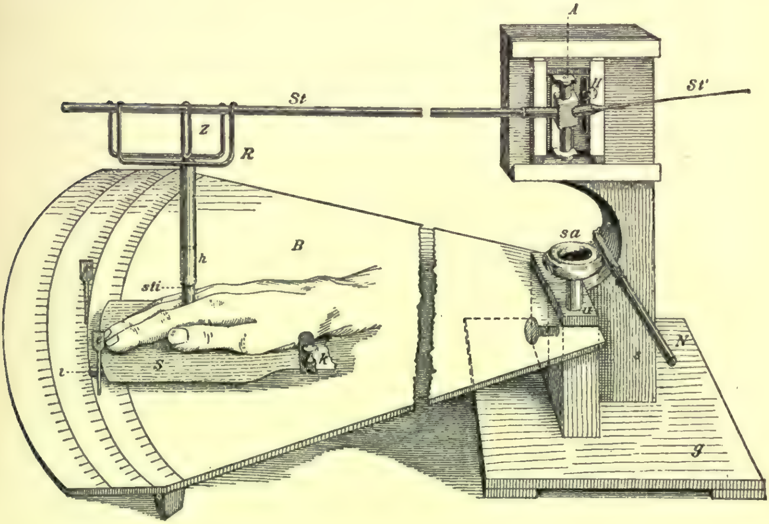


FIG. 43.—Kinematometer.

(From Störring, *Philos. Studien*, XII. Engelmann.)

members of their body, as long as their "joint" sensations are preserved. If these are also wanting, they no longer possess sensations of position. The patient in Fig. 44 was without cutaneous sensitivity and joint sensitivity in the right arm. With open eyes he could hold both hands in the same position, but if his eyes were shut, the position of the right hand changed without him being aware of it.

(b) *Effort.*

In all active movements, *e.g.* if I raise a weight or make a voluntary movement in the kinematometer, sensations of effort are added to sensations of position. They seem chiefly to have their origin in the muscles and

FIG. 44.—A patient lacking cutaneous sensitivity and joint and muscle sensitivity in the right arm. With his eyes open he can raise both hands to the same position ; as soon as he shuts his eyes the position of the right hand changes unconsciously and involuntarily.

(From Strümpell, *Zeitschrift für Nervenkeilkunde*, 1902. Vogel.)

are difficult to analyse because they are always bound up with sensations of position. They can best be investigated by lifting weights.

(c) *Movement.*

Sensation of movement is in the main a complex chiefly of sensations of effort and position. The difference

sensitivity of sensations of movement can be investigated by means of the kinematometer. I move the arm of the observer from the original position along to a certain point and then back again (passive movement), and now

FIG. 45.—Young children exercising the large joints.

(From Tadd, *Neue Wege zur künstlerischen Erziehung der Jugend.* Voigtländer.)

I tell him to move it back again to the same point (active movement).

It seems as if the difference sensitivity of children for movements of the larger joints is comparatively greater than that of adults. If this is verified it means that we should begin to develop the whole hand and arm of

small children before going on to the development of the finer joints like those of the fingers. This would support the latest methods of teaching young children to draw, by which the arm is first of all brought

FIG. 46.—Difference sensitivity in lifting weights. Weber's Law.

into play. Fig. 45 shows American children at the blackboard.

The organic sensations (*e.g.* hunger), which are generally included among touch sensations, can be only mentioned here, because it is almost impossible to experiment with them.

III. WEBER'S LAW

I tested the difference sensitivity of the above-mentioned nine-year-old girl for lifting weights. I put a light dish with a 100 gr. weight into her right hand. Her eyes were blindfolded. She was told to lift the dish once up to about the height of her eyes and then to lay her hand down again on the table. A soft covering should be on the table. I then put another similar dish with a 101 gr. weight into her hand, and told her to lift it as before. No difference was noticed. Then followed the normal weight again (100 gr.), and then for comparison 102 gr. and so on. At 120 gr., *i.e.* at 20 gr. difference, a difference was noticed.[1]

I then went through the experiment with a 50 gr. weight. Already at 61 gr. came the judgment "heavier." Therefore with a weight half as heavy as the former, only about half as much needed to be added in order that a difference should be perceived. We see therefore that the addition to the stimulus, which is needed to call forth a just noticeable difference in the sensation, must stand in the same proportion to the normal stimulus. I must each time add $\frac{1}{5}$ of the normal weight to make a difference perceptible.

We have thus arrived at the law, which gets its name from the discoverer, Ernst Heinrich Weber. In its simplest fashion we can formulate it thus :—

The additional stimulus that is necessary in order to proceed from one given sensation to another just noticeably greater, is always for that particular sense a constant fraction of the given stimulus.[2]

[1] The same experiment with the mother showed that she was superior to her child in lifting weights. At 116 gr. came the judgment "heavier." Compare on the other hand the colour-sensitivity, page 63.

[2] This is the simplest expression for the facts under discussion. Generally Weber's law is so formulated :—The stimulus must increase in

This fraction is $\frac{1}{5}$ for the child in question in regard to the lifting of weights. If I begin with this child at 20 gr., I must add 4 gr., if at 200 gr. I must add 40 gr. and so on, always on the supposition that Weber's law holds good.

What does Weber's law mean ?

We must call to mind that it is really incorrect to speak of measuring sensations. We have not measured sensations but the relations of two sensations to each other.[1] In all our measurements we had to compare two sensations with each other.[2] And it is the accuracy of our comparison that we have measured and not really the size of the sensations.

If this is true then Weber's law must possess universal validity, wherever a comparison of the intensity of two sensations takes place. This seems actually to be the case. It has proved itself valid above all in investigations on pressure and force sensations (the pressure and lifting of weights), and on the intensity of light and sound sensations.

There are exceptions to Weber's law, just as there are to every other law. We shall soon learn one of the most important of these exceptions.

geometrical progression in order that the sensation may increase in arithmetical progression ; or :—Sensation is proportional to the logarithm of the stimulus. Fechner came to this formulation by help of the differential calculus. These two formulations however are only valid on the hypothesis that sensations (or sensation-differences) can be measured according to their absolute value, a supposition that we cannot accept. We recommend therefore for child psychology and pedagogy the simple formulation given in the text, which does not need any such hypothesis.

[1] Strictly speaking our chapter ought not to be called "The Measurement of Sensation," but rather "The Measurement of the Power of comparing Sensations."

[2] This also holds good in the determination of the stimulus threshold. I can only perceive the existence of the very weakest, just noticeable sensation in comparison with minimal sensations that always fill our consciousness. No absolutely quiet place exists. There is no absolute darkness. If I shut my eyes in the darkest room, I still have quite a number of very weak, subjective sensations of light.

Ebbinghaus gives in his *Grundzügen der Psychologie* the table printed below for the difference sensitivity at different degrees of brightness.

Light Intensity.	Difference Sensitivity.	Light Intensity.	Difference Sensitivity.
0·5	$\frac{1}{4}$	500	$\frac{1}{51}$
1	$\frac{1}{6}$	1,000	$\frac{1}{57}$
2	$\frac{1}{8}$	2,000	$\frac{1}{59}$
5	$\frac{1}{14}$	5,000	$\frac{1}{61}$
10	$\frac{1}{21}$	10,000	$\frac{1}{60}$
20	$\frac{1}{27}$	20,000	$\frac{1}{57}$
50	$\frac{1}{33}$	50,000	$\frac{1}{47}$
100	$\frac{1}{40}$	100,000	$\frac{1}{34}$
200	$\frac{1}{45}$	200,000	$\frac{1}{26}$

We see from this table that to a light of the intensity 1, we must add a sixth to perceive the difference ; of the intensity 2 an eighth, and so on. The brightness of the intensity 1 was about equal to the light that one would get "if one were to let the light of an ordinary good stearine-candle fall on to a very white piece of rough paper from a distance of $\frac{3}{4}$ metre, and then to look at this light through a small hole one square mm. large. The intensity 2000 equals the lighting of the same paper from the same distance by a strong uncovered electrical arc-lamp of 2000 candle-power."[1] We see at once from the table that Weber's law is only valid for the middle degrees of brightness, from about 2000 to 10,000 candle-power. Only here is the addition of brightness that is necessary to call forth a new sensation constant, namely about $\frac{1}{60}$. On the other hand, with very weak or very intense stimuli the sensitivity is much less, *i.e.* not so fine.

The explanation of this difference is obvious. In the middle degrees of brightness, to which our eyes are accustomed, from the sunlight-flooded landscape down to a

[1] Ebbinghaus, *Grundzüge*, Bd. I. p. 523.

dull daylight, the relations of the separate intensities of light do not alter, although the general brightness may be at times different. Therefore the whole picture remains pretty much the same for our sense-perception in bright or in dull daylight. Only when it becomes considerably brighter or darker, do these relations alter, and then our whole perception of it alters as well. It happens by very weak light that we cannot judge relations between things at all.

What can pedagogy expect from investigating Weber's law on children? [1]

We may say that the more precisely Weber's law appears in a child, the more is his faculty of comparison developed, *i.e.* the faculty of comparing separate sensations with another in regard to their intensity.

Secondly we may note how large the "middle region" is, within which Weber's law holds good. There must lie the stimuli, which are adequate for the sensation of children. It is possible, for example, that among children much stronger intensities of sensations of hearing belong to the normal sensations than among adults. We could test this, of course, by seeing whether Weber's law holds good for them within the same region.

Then again in regard to the sense of colour, if the child is more sensitive to simple pure colours, then Weber's law in regard to the intensity of the mixed colours will not be as precise as for adults.

Those regions, of course, should be first of all investigated for the purpose of comparison, where Weber's law has proved itself valid for adults, *e.g.* for the intensity of sound sensations.

For such experiments Zoth's accoumeter is good (Fig. 47). An electro-magnet holds a small steel ball

[1] No important investigations are known to the author.

which, when the current is broken, falls on a smooth steel plate. The determination of the objective intensity of

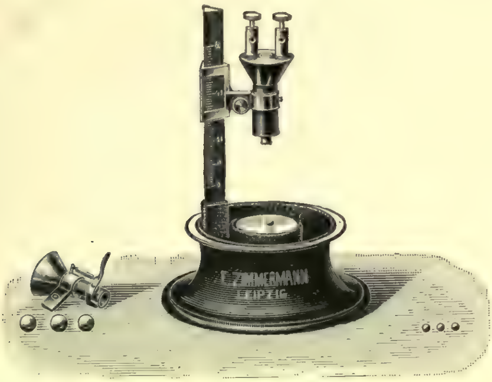


FIG. 47.—Zoth's accoumeter.

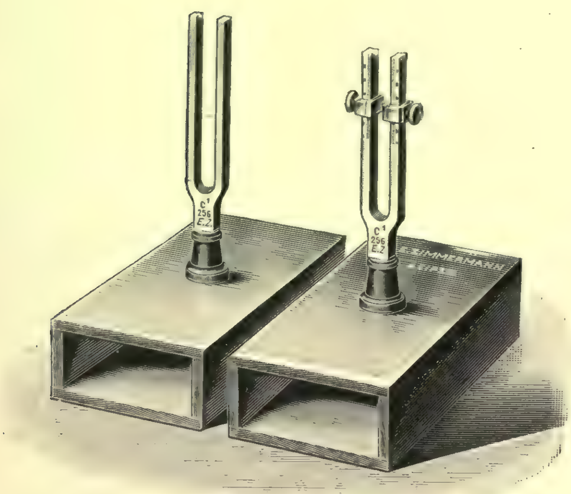


FIG. 48.—Tuning-forks to determine difference sensitivity.

the sound is fixed by taking the product of the weight of the ball and the height of fall (which can be read off a

scale) as the measure. The method of investigation is the same as the determination of any difference threshold.[1]

[1] By using the small ball in Zoth's apparatus we can investigate the stimulus threshold. It is often used to determine the sharpness of hearing in anthropometrical measurements, which often include a test of the senses. The test is made either with the apparatus itself or by using a watch. The ticking of the watch is compared with the apparatus by fixing from what height the smallest ball must fall in order to give a sound which is equal to the tick of the watch. With this watch the tests can be made. If different watches are of different intensities, these differences can also be fixed, and the watch with the greater intensity will be used at a correspondingly greater distance.

We add here the simple method by which the difference threshold for tones can be determined. Two similar tuning-forks are used. One of them has a sliding weight to make the tone deeper (Fig. 48). According to the method of limits the normal fork is first struck and then the second, which is tuned much lower. The difference is then gradually lessened, until equality appears and so on, as in every experiment according to the method of limits.

CHAPTER III

PERCEPTIONS AND IDEAS

I. SPATIAL PERCEPTION

1. Spatial Perception by Touch

Perceptions, like all other psychical complexes, can be divided up into their elements, sensations. They are not however a mere sum of these elements. In their composition there arises by means of the arrangement of sensations something new, in the first place their spatial and temporal characteristics.

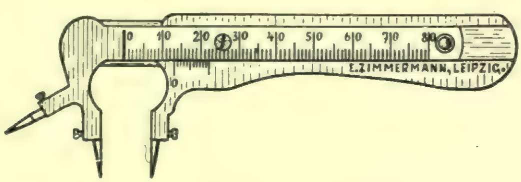


Fig. 49.—Spearman's æsthesiometer.

Our spatial perceptions, as is well known, arise chiefly by means of the senses of touch and sight.

To test our spatial touch perceptions we must go back to the simplest case.

If we touch a certain part of the skin with a stimulus hair (Fig. 37) we not only get a pure sensation of touch, but we localise it on a certain part of our body, by arranging it in space with the help of indistinct associations of spatial sight ideas. The accuracy of this arrangement I can measure, if I let two stimuli work upon the skin quite near each other. I can do this with the help of

an æsthesiometer (Fig. 49). The apparatus is made of aluminium so that it may be placed upon the skin lightly.[1]

If I wish to measure the spatial threshold of the touch sense with this apparatus, I begin with the single point and then place the two points very close together on the skin, and so on [2] until the child notices that there are two points (Fig. 51).

The spatial threshold of the sense of touch is very different on different parts of the skin. On the finger-tips it is 1 to 2 mm.; on the upper arm it is 6 to 7 cm. With children it is a little smaller. They are therefore more sensitive than adults. The cause of this can easily be explained. The surface of the skin increases considerably by growth, and very few new nerve-endings arise. Therefore the adult has far fewer pressure spots on a square centimetre of skin than the child has.

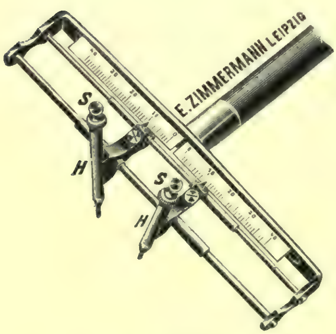


FIG. 50.—Ebbinghaus' æsthesiometer.

The spatial power of the sense of touch always works, as we have before mentioned, with the help of associations of visual space ideas, and the closer these two elements, the spatial touch and sight ideas, are melted together, the more is gained for the formation of spatial perceptions. Just here lies the great value of modelling and similar

[1] Any ordinary pair of compasses may be taken if used carefully. The distance between the two points must be carefully measured each time and both points must touch the skin simultaneously. It is well to blunt the points slightly. *Cf.* Ebbinghaus' Æsthesiometer (Fig 50).

[2] According to the method of limits.

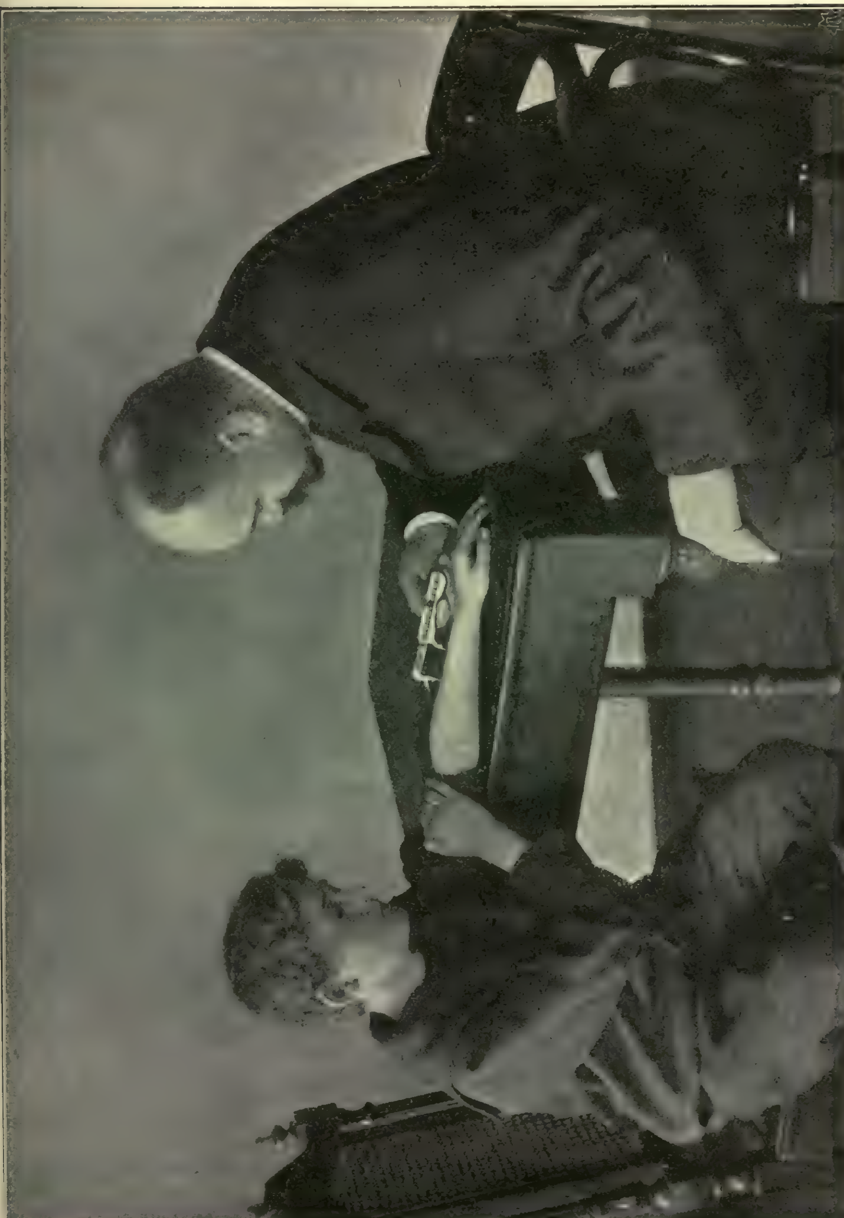


FIG. 51.—Determination of the tactual spatial threshold.

activities, not in using the sense of touch alone. Touching an object on all sides, running a pencil over the outline of a picture, modelling—all these activities help to develop the spatial sense best of all when the eyes give their assistance. Fig. 52 shows how the spatial touch and

Fig. 52.—Children modelling. Drawing-room in an elementary school in Leipsic.

(From Weissenborn, *Neue Bahnen*, 1906.)

sight perceptions melt into one by means of the attention when the child is modelling.

Those blind from birth cannot of course have associations from visual perception, they must therefore make use of different means to help themselves to proceed from the local signs of the organs of touch to spatial perception. In fact they use associations from internal sensations of touch, as is clearly shown in the reading of the blind.

They first of all run over with the fingers of one hand the letters of the text, which are formed of raised points, and they let the other hand follow closely after feeling each

Fig. 53.—A blind girl reading.

point. The image of the movement of the first hand is associated with the simple touch sensations of the second. They thus achieve some sort of spatial sense-perception of the letters and are so able to read. The girl shown in Fig. 53 reads correctly and fluently like a normal child. Such a capacity is of course only possible owing to the

fact that among the blind the spatial threshold for touch sensations and the difference sensitivity for sensations of movement become very fine through practice. Normal children could also achieve a similar perfection with sufficient practice. Since with the latter the visual spatial perceptions make up the chief part in the formation of spatial perception, the development of the internal touch sensations is neglected. The unfortunate ones, who are shut out by fate from the world of visual perception, show us clearly how lavish nature has been to man in the possibilities of mental development, so lavish that even the blind are able to attain a spatial image similar to that of the normal human being.

2. Spatial Perception by Sight

In testing our perception of space from sight let us start, not with the stimulus threshold, but with the difference threshold. For this purpose we draw two lines near to each other, but not too near. Then we increase one of them a little at a time until a difference is noticed. For very accurate investigations the apparatus for testing the spatial threshold is used (Fig. 54). For marking off the distances two points are used. They are marked on two glass sheets that lie one on the other, and these sheets of glass can be screwed up or down by means of a handle, and so the points come nearer or move further apart.

As with the sense of touch, the perception may take place when the eyes are at rest or in motion. I can fixate an object or follow a line with my eyes.

If I wish to investigate, whether the spatial perception of the child is more exact when the eyes are at rest or in motion, I can let one form (say a triangle) be compared with another in two different ways. Either a special

point must be fixated or the eyes must follow round the outline of the figure. We can then easily determine by which method of observation the judgments are more accurate. I may also use for my investigations the well-known optical illusions, which like the Müller-Lyer illusion

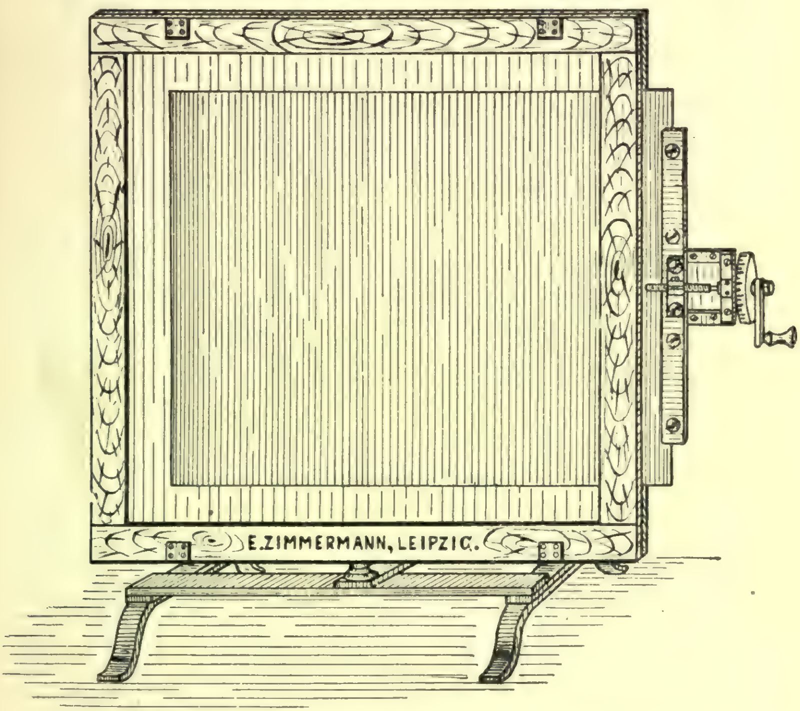


FIG. 54.—Apparatus for testing the visual spatial threshold.

(Fig. 55), arise because eye-movements take place. In Fig. 55 the eye underestimates the upper line because of the short oblique lines that lead the eye inward, and similarly overestimates the lower line. These illusions appear in children just as well as in adults. It proves that in children the eye-movements take the same part in the development of visual spatial perception.

Accurate investigations[1] of the difference threshold for spatial sight perceptions of children show that six-year-old children can judge as accurately as fourteen-year-old ones, and that the six-year-old ones are on an average better than adults. It would be of great use if these results were further verified. The investigation can be carried out without any apparatus. Giering gives all details as regards method. If Giering's results hold good, and we can scarcely doubt them, then we must demand in our educational system that more attention be paid to the development of the spatial perception of the child in the first years of school by means of drawing, modelling, &c.

The girls were inferior to the boys in the difference

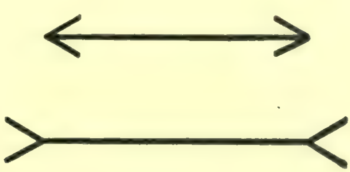


FIG. 55.—The Müller-Lyer illusion.

sensitivity, because the six-year-old boys gave much better judgments than the fourteen-year-old girls. This result should also be verified. If it proves true, we must discuss the problem, as to whether it would not be better to pay more attention to the extraordinary colour-sensitivity of young girls (see p. 62) instead of to their spatial perceptions.

Besides the estimation of the lengths of lines, we can also test the comparison of surfaces of different magnitude with each other, the estimation of the distance of an object and the perception of depth. It is of special importance to consider how the different elements in the child's perception of depth, those obtained from touch and those

[1] Giering, H., *Das Augenmass bei Schulkindern, Zeitschr. für Psychologie*, Bd. 39. 1905.

from sight, are related to each other. No such experiments are known to the author.

Fig. 56 shows an apparatus by which we can test as to whether we can estimate with one eye the distance of a rod or of a thin string, which can be brought nearer or moved away from the eye.

In conclusion let us repeat again that in spatial perception the best results are always obtained when perceptions of sight and of touch are combined together. Printed letters, for example, will be much better remem-

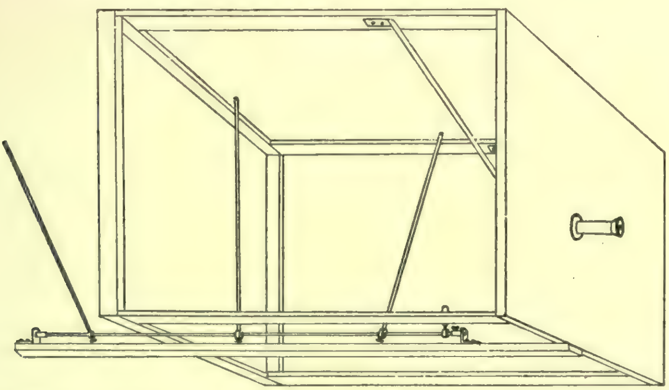


FIG. 56.—Apparatus for testing the accuracy of our perceptions of depth.

(Giering, *Zeitschrift für Psych. u. Physiol. der Sinnesorgane*, Bd. 39. Barth.)

bered, if they are divided up into their elements and then put together again by the children say with little pieces of wood (Fig. 57). And so on in all elementary instruction.

II. TEMPORAL PERCEPTION

1. The Difference Threshold of the Time Sense

Spatial perception is very well developed in the child. The development of temporal perception seems

to lag behind.[1] This is, of course, of great importance for pedagogy, not only in regard to all historical subjects, but also in regard to the age for beginning arithmetic, which is essentially based upon temporal ideas, *e.g.* counting.

An exact investigation can only deal with short periods of time, which can be directly perceived (according to Meumann from ·3 to 1·5 seconds). The investigation of

FIG. 57.—Reading lesson in an elementary class in the Werner-Siemens Realgymnasium, Berlin.

(From Wetekamp, *Selbstbetätigung und Schaffensfreude.* Teubner.)

the difference sensitivity is most easily arranged in the following manner. Three successive beats are fixed on some apparatus for measuring time, so as to mark two intervals of time, that are to be compared. The apparatus usually used is so expensive that I can recommend the following simple arrangement.

[1] *Cf.* Meumann's *Vorlesungen.* Leipzig, 1907.

The metronome shown in Fig. 58 is well-known in experimental psychology. It differs from the ordinary metronome only in the fact that at each beat a little piece of wire (left and right) dips into a small cup of mercury, by means of which an electric circuit is opened or closed. We let the metronome make three beats (after the third it must be stopped by the hand), and thereby obtain the two periods of time required, but these are not suitable for investigation because they are exactly equal. Now

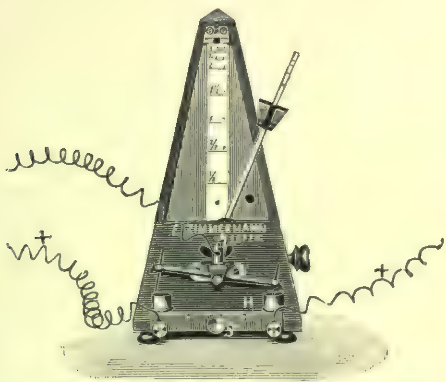


FIG. 58.—Metronome with electrical contacts.

a metronome only goes regularly as long as it stands upright. If I lean it over slightly to one side, one of the beats will be a little longer than the other. I therefore go on leaning the apparatus always a little more over to the one side, until the observer perceives a difference in the time intervals. All that remains now is to measure the times. This is very simple. Each beat of the metronome closes an electric circuit, when the wire dips into the mercury. By means of an ordinary electro-magnet with a writing-point and a kymograph (see p. 174, Fig. 153), the three points of time are marked. The distance between them gives us the length of the time periods.

2. Individual Differences

It is an old subject of discussion as to whether great individual differences in regard to temporal perceptions already make their appearance in the child. Many people maintain this. They say that the sense for rhythm and measure, the sense for temporal ideas in general, is almost wanting in some children.

This of course would explain in the easiest manner the failure of such children in arithmetic and music.

There are many, however, who deny the presence of such fundamental differences, and therefore an investigation of the matter is very appropriate.

It can be conducted in the following manner. The child is told to tap on a tapping-key at any speed it chooses. Each tap closes an electric circuit within which there is an electro-magnetic writing-point. This records each tap on the smoked drum of a kymograph (Fig. 151). We can then see whether the tapping of the child was rhythmical or not. From this we can tell how accurate the time sense of the child is.

Fig. 61 shows the first curve of a nine-year-old child according to this method. The upper line is the tapping-curve, the lower one marks fifths of a second recorded by the Jaquet chronometer, which is shown in Fig. 149. We can see that the child quite of its own accord tapped rhythmically.

It is a more difficult test when the teacher taps a definite measure, which the child must repeat. Fig. 60 shows first the teacher's curve and then the child's copy. At first, as we can see from the curve, the child reproduced the beat very well, but when the child was told to continue, the rhythm slowly changed into its favourite rhythm (Fig. 61. Compare this with Fig. 59).

Two values can be measured by such investigations; firstly the individual rhythm of each child or of each class, and secondly the difference sensitivity for temporal

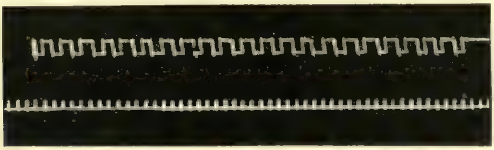


FIG. 59.—Tapping in rhythm at pleasure. Kymograph curve. Below: time record, ⅕ sec.

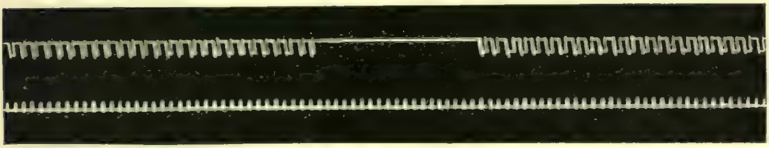


FIG. 60.—Tapping according to a prescribed rhythm. The prescribed rhythm is at first well produced.

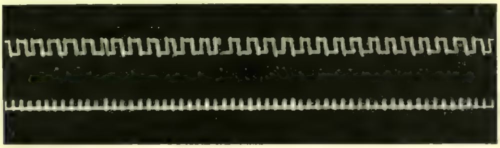


FIG. 61.—End of curve in Fig. 60. The child reverts gradually to his former rhythm (Fig. 59).

perception, *i.e.* the accuracy with which a certain rhythm can be imitated.

If a teacher of singing has tested his pupil in regard to the difference sensitivity for temporal perceptions and for tones (pp. 86–88), he has obtained the essential characteristics of his musical talent.

III. STATISTICS OF IDEAS

1. An Analysis of the Child's Store of Ideas with the Help of Speech

Up to this point we have directed our attention to the purely formal side of the formation of ideas. There now remains for investigation the content of ideas.

We are here most of all interested in the store of ideas which the new pupil brings with him to school. Our first instruction must of course start from this source. We can get insight into this store by a very simple statistical method. We ask the child if he has seen a butterfly, a lark, an apple-tree, a coal-mine, &c. This is called the question method.[1]

An improvement on this method was employed by Seyfert [2] by showing the child the objects themselves, or at least pictures, and then calling upon the child to name them (the naming method). The advantages of this latter method are of course obvious.[3]

2. An Analysis of the Child's Store of Ideas with the Help of Drawing and Modelling

There are two objections to the two methods described above. Firstly they take up a great deal of time, as each child must be questioned separately, and secondly, because of this, the investigation is generally limited to a small and definite number of ideas (perhaps 100). This

[1] *Cf.* Hartmann, Dr. B., *Die Analyse des kindlichen Gedankenkreises*, 4 Aufl. 1906.

[2] Seyfert, Dr. R., *Beobachtungen an Neulingen*, *Deutsche Schulpraxis*, 13 Jahrg. Nr. 11 and Nr. 23–26. Leipzig, 1893-4.

[3] Full description in Meumann's *Vorlesungen.*

method shows us what the child does not know rather than what he knows.

We want a method, therefore, by which the child can spontaneously show and give expression to his store of ideas. This method we find in the spontaneous drawing and modelling of the child.[1]

A quite general test may be given, such as, "Draw what you like." Or special tests, "Draw something at the sea-side, or in the town, or in the room," &c. Such tests can be carried out in a short time for all the children at once.

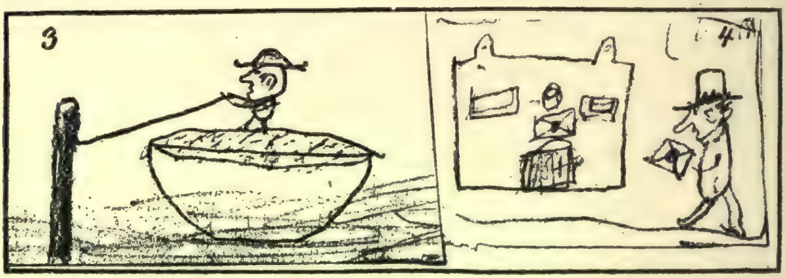
From these investigations we see first of all what is of greatest interest to the child, what it is he longs to express. In the four drawings of a Hamburg child shown in Figs. 62 and 63, we see at once the "sea-urchin," the child that lives by the sea. We notice the barge with coals, and the bargee pushing his barge away from the pile, and then the steamer with its funnel and flags, the stormy sea and the gulls. What a number of ideas in these two drawings!

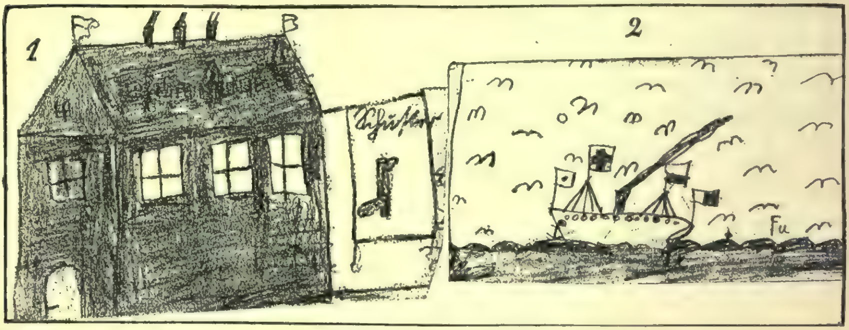
What a deep insight into the constitution of a store of ideas spontaneous drawings may give, can be seen from Figs. 64, 65, and 66, which show drawings from memory of the insane. Fig. 64 shows clearly the tattered condition of the world of ideas of the unhappy patient. Fig. 65 gives us quite a different picture. This patient is in an advanced stage of disease. She covers sheet after sheet of paper always with the same coins and animals. The poverty of ideas of this patient, the continual recurrence to ideas of the same content, is clearly shown in her drawings. Fig. 66 lets us get a glance into the world of feelings of the patient. He suffers from hallucinations of

[1] Kerschensteiner, G., *Die Entwicklung der zeichnerischen Begabung.* Gerber, 1905. Lewinstein, S., *Kinderzeichnungen bis zum* 14. Lebensjahre. Voigtländer, 1905.

the most terrible sort, and the gruesomeness of his ideas is shown in his drawings. We also note the unsteadiness of his ideas as in Fig. 64.

These are three cases of adolescent insanity, each with





FIGS. 62 and 63.—Drawings from memory by a Hamburg child.

(From Weber, *Neue Bahnen*, May 1906.)

its peculiar disturbance of its store of ideas, which in all three cases is shown clearly in the drawings.

Just as Dr. Mohr proposes to use the drawings of the insane as a help in diagnosis, so we could perfect our diagnosis of normal children when they enter school by studying their drawings.

We could use modelling in a similar manner, where

the necessary technical skill is present. Fig. 67 shows the work of children of different ages. Not only do we

FIG. 64.—Drawing from memory by an insane patient (adolescent insanity).

(From Mohr, *Zeitschrift für angewandte Psychologie*, 1908. Barth.)

see in this work the advance in technical skill and in spatial ideas, but also the vastly different field of ideas, from which each child takes its ideas.

Statistics of ideas give the teacher a starting-point for his school-work. He will find different material accord-

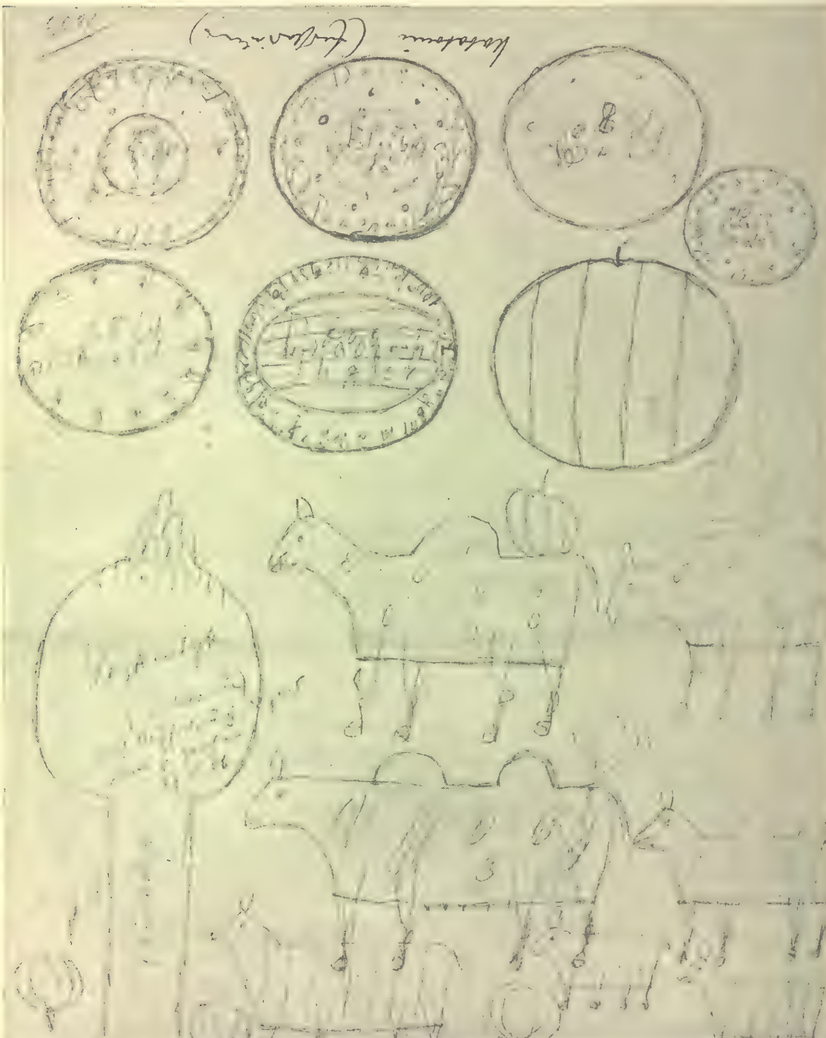


FIG. 65.—Drawing from memory by an insane patient (adolescent insanity in an advanced stage).

(From Mohr, *Zeitschrift für angewandte Psychologie*, 1908. Barth.)

ing as his children come from a hilly or a flat country, a city or a country-place, from rich or poor parents.

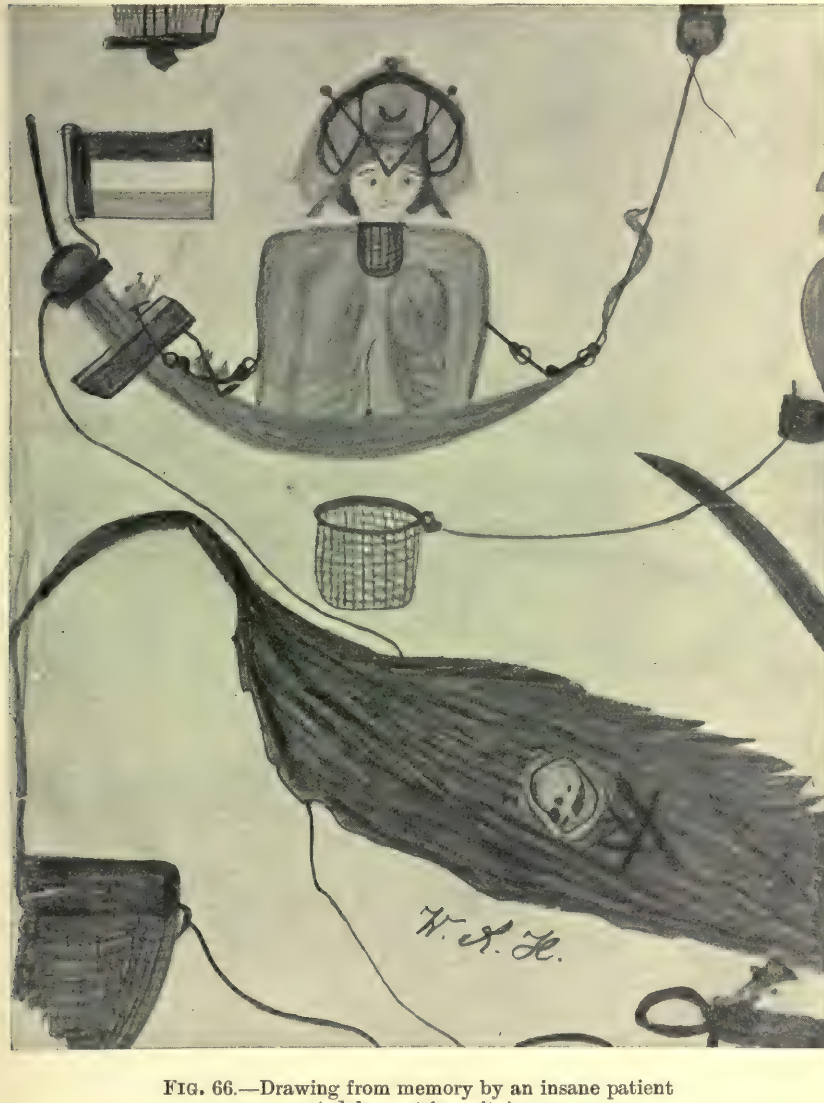


FIG. 66.—Drawing from memory by an insane patient (adolescent insanity).

(From Mohr, *Zeitschrift für angewandte Psychologie*, 1908. Barth.)

Lotte W.: 1. (Age $5\frac{1}{2}$) Funnel. 2. (Age $5\frac{1}{2}$) Bat. 3. (Age 6) Windmill. 4. (Age $6\frac{1}{2}$) Daisy. 5. (Age $6\frac{1}{2}$) Mother bathing child. 7 and 8. (Age 6) Lamp and hat

Lotte W.: 1. (Age $5\frac{1}{2}$) Frog. 3. (Age $6\frac{1}{2}$) Snail. Helmut W.: 2. (Age $3\frac{3}{4}$) Pig. 4. (Age $4\frac{1}{2}$) Horse. 5. (Age $6\frac{1}{4}$) Sheep. 6. (Age $6\frac{1}{2}$) Goat.

Helmut W.: 1. (Age $6\frac{3}{4}$) Sleeping dog. 2. (Age $6\frac{3}{4}$) Policeman. 3, 4, and 5. (Age $6\frac{3}{4}$) Stag family. 6. (Age $6\frac{3}{4}$) Horse with harness.

FIG. 67.—Development of the sense of form of a sister and brother from the age of 5 to 6.

(From Weissenborn, *Neue Bahnen*, 1905–6.)

It would be entirely wrong, if he were to make these differences the starting-point and foundation for a difference in schools. Say, for example, the differences between rich and poor children as an argument for the advantages of our English elementary and preparatory schools. For the sum of ideas that the six-year-old child brings to school depends upon the experiences that a child has been able to gather in favourable and unfavourable conditions and not upon his capacity or talents.

A different kind of school, if its existence is necessary, can only have a scientific excuse, if it is based upon differences of intellect and talent. Here investigations of the difference sensitivity, the memory, &c., are alone conclusive.

CHAPTER IV

FEELINGS

I. THE METHOD OF OUTWARD EXPRESSION

However different the definitions of the nature of feeling may be among psychologists, they very nearly all agree in one point, and that is that the feelings are those processes of consciousness that lie nearest to our self.[1] For example, Wundt says, "Feeling is given us in experience, as a subjective reaction of consciousness on an outward impression."

We see at once from this that there will be special difficulties in investigating the feelings. If introspection (self-observation), especially for children, is in any case difficult, how much more difficult must it be if the processes to be observed stand in the closest relation to the observing self, as is the case with feelings.

There is, however, another difficulty. Sensations are comparatively constant phenomena. If I observe the green of a meadow for a certain time, the green sensation by no means remains the same, it begins to change from the very first moment of observation. This can be easily proved by observing the colour only with one eye and then from time to time by opening the other eye in order

[1] The simple feelings are along with the sensations the only elements of consciousness. They should therefore really have been treated before our chapter on perceptions and ideas. We must remind the reader again that our book is arranged rather to follow the methods that may be employed. Had we followed the psychological sequence we should have had to separate the simple and compound feelings, and we deem it best to deal with these in one and the same chapter.

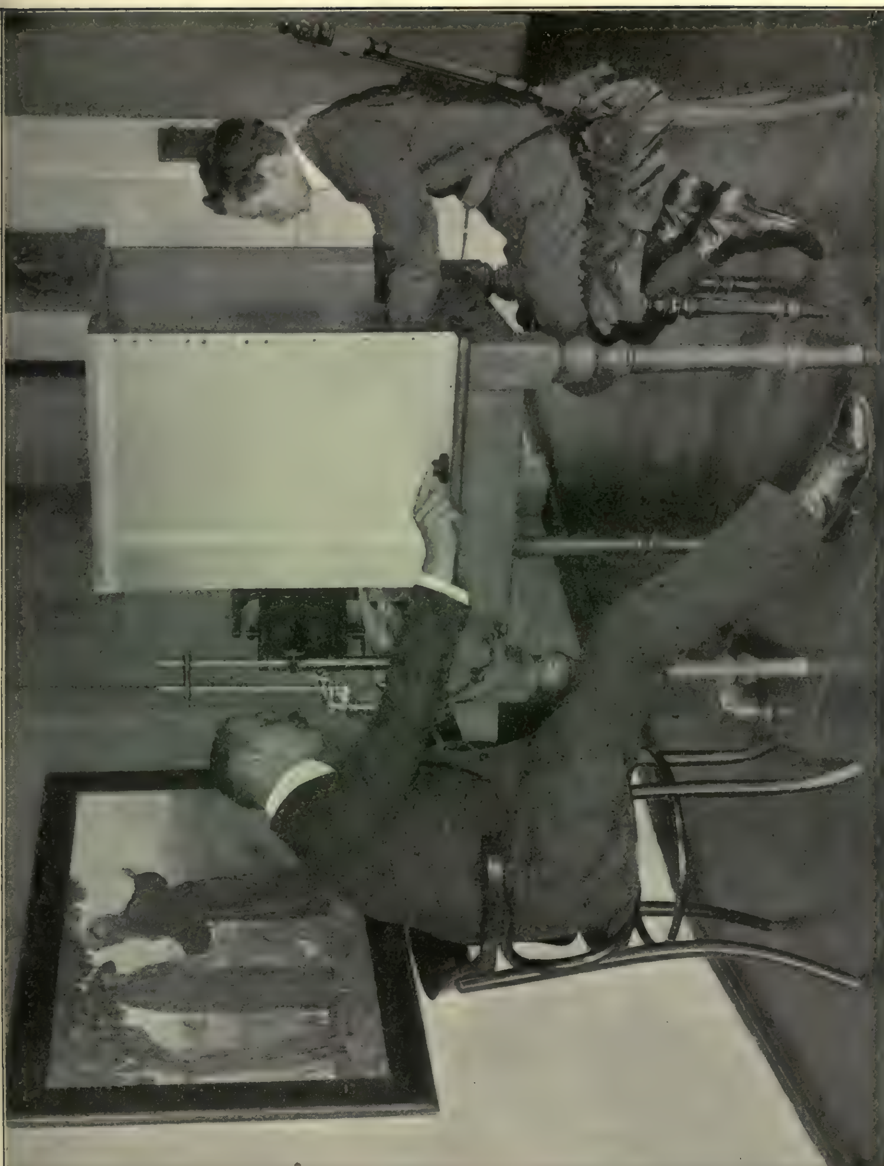


FIG. 68.—Arrangement for experiment to investigate the pulse and breathing while looking at pictures.

to compare the change that has been going on. We see from this how a colour loses in saturation for an eye upon which a colour stimulus is working continuously. And yet this is only a difference in intensity. On the other hand everyone knows that with feelings, in accordance

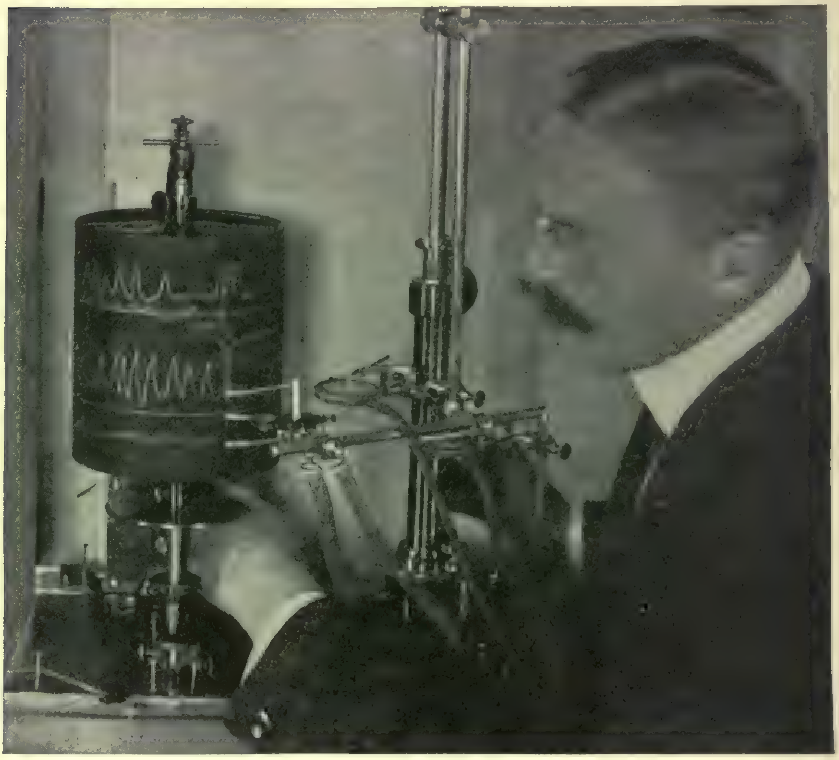


FIG. 69.—Kymograph and recording apparatus for experiment shown in Fig. 68.

with their subjective nature, we have to do with a very changeable affective process, whereby one feeling may in some circumstances change into its exact opposite. The most beautiful melody may become unbearable if we are forced to hear it a thousand times in succession. A

sensation, however, is in its essence the same even if repeated a thousand times.

There is still a further difficulty. In experimenting with sensations, we used the simple impression method.[1] We set a stimulus, an impression, to work and observed the changes in our consciousness. These pure impression methods can only be indirectly used in experimenting on the feelings. Suppose that a person feels a certain sweet substance unpleasant. I dare not draw the conclusion that there is some anomaly in feeling in this case. It may be that because of some physiological changes, the observer has not the sensation of sweet at all. Naturally therefore the usual feeling of pleasantness cannot arise. In this case it would not be an anomaly of feeling but of sensation. We must therefore, in using the impression method, always ask two things, firstly whether the expected sensation has arisen, and secondly, what feeling arose in connection with it.

1. The Nature of the Expression Method

In face of these difficulties it is very good that we possess another method for investigating the feelings, the so-called expression method.

The expression method agrees with the impression method in so far as we set a stimulus to work, the effect of which is controlled by introspection (this time of course of the feelings). Alongside of this, however, the experimenter observes certain bodily changes, the so-called expression movements of the observer. The study of these movements is the essential part of the expression method.

[1] All methods of experimental psychology are in reality impression methods. But it is usual to call those, which only make use of the impression of a stimulus and the following introspection, impression methods.

Everybody knows that the expression of the face changes under the influence of strong feelings; that the heart beats differently, that the rhythm of breathing is different, when we are moved by pleasure or pain. We all know that sorrow or great joy may cause tears to flow. The flow of the secretion of certain glands is also influenced by our feelings.

The expression methods try accurately to determine (quantitatively) all these bodily symptoms, and thereby arrive at definite conclusions.

The following bodily changes can be measured :—

1. The real expression movements.
   (*a*) The movements of mimicry, facial changes of expression.
   (*b*) Pantomimical movements, the changes in the movements of the members of the body and of the whole body.
2. The so-called expression movements.
   (*a*) Changes of the pulse.
   (*b*) Changes of the breathing.
   (*c*) Changes in the secretion of glands.

2. The Use of the Expression Method

Let us suppose that we have established by a number of experiments on children, that a feeling of pleasure makes the heart beat slower and stronger than usual. We now experiment on a new child, and we find the pulse quite normal, in accordance with an indifferent state of feeling. Suddenly we notice that the pulse is beating more strongly and more slowly. It would be quite false to conclude that the child has now a feeling of pleasure. For a thousand other things may cause the pulse to slow down and beat more strongly. Even in the case where we

set a stimulus to work (say sugar), from which we expect a feeling of pleasure, the fact that the pulse alters in a certain way does not in itself justify us in drawing any conclusion as to the feelings of the observer. We need always the statement of the observer as to his feelings.

We involuntarily ask, "What is the use then of this expression method?" Wundt's answer to this question is, "The appearance of these symptoms is not a proof but an index of the existence of a certain affective state."

What this means and what results the expression method has arrived at may best be seen from a history of the psychology of feeling. One of Wundt's pupils was the first to investigate the changes of the pulse under the feelings of pleasure and pain, and found certain relations between these feelings and the changes of the pulse. There appeared, however, by certain feelings of pleasure and pain other changes of the pulse, which could not be arranged under the general law established, and which were, therefore, difficult to explain. Wundt regarded this as a sign, that perhaps the old theory of feeling, which accepted only two simple qualities (pleasure and pain), might be wrong, and that with keener introspection we might discover other simple feelings. And his introspection led him actually to the assertion that other pairs of feeling exist, namely arousing and quieting feelings, and feelings of strain and relaxation. This was the way in which Wundt's three-dimensional theory of feeling was introduced into psychology based on the results of the expression method.[1]

[1] There still exists no unanimity as to which changes of the pulse correspond to the particular feelings. If for this reason alone many psychologists do not accept the three-dimensional theory, then they do not understand the meaning of the expression method. It can only help observation, it can never arrive at decisive psychological results. The real decision of such a question must rest on introspection.

In pedagogy we can use the expression method in a similar fashion. Let us choose a very difficult case. Three new pictures are given to us to judge—Fig. 70, "The Young Man of Nain;" Fig. 73, "Abraham and Lot;" Fig. 76, "The Storm on the Sea of Galilee" [1]—pictures that undoubtedly strongly affect adults, and each picture in a particular way.

Will these pictures also cause strong and different feel-

FIG. 70.—"The Young Man of Nain."

(Voigtländer, Leipzig.)

ings in school-children? Of course we could ask the children, as many psychologists would propose to do in such a case. Anybody who has to deal with children would know what the result would be. Nothing is more difficult than to get a statement of their feelings from them, and therefore nothing is more absurd than to put such questions, without testing the truth of their answers by some

[1] Lithographic drawings of Haueisen, published by R. Voigtländer, Leipzig.

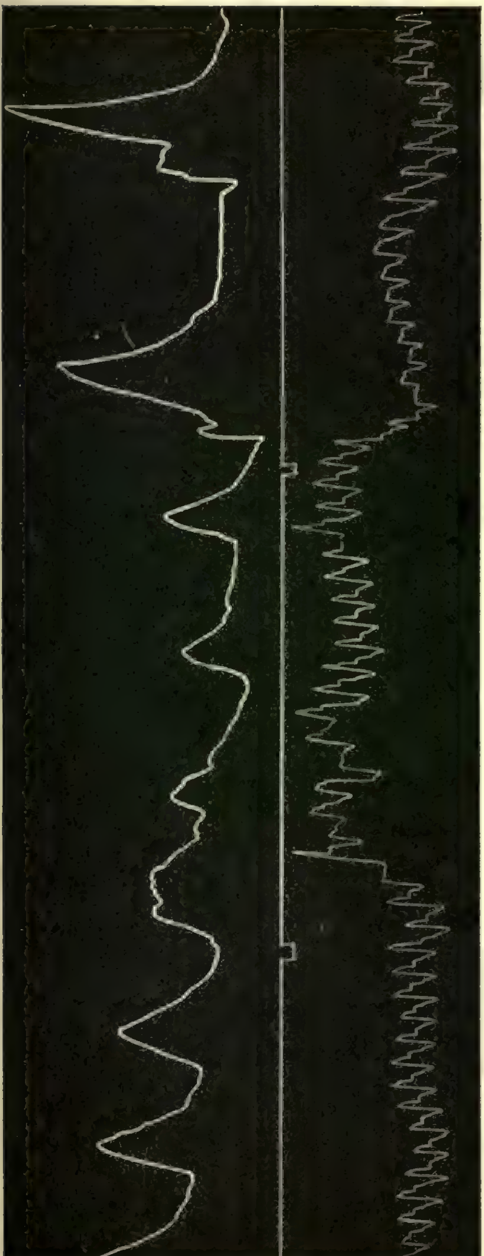


FIG. 71.—Breathing and pulse curves while looking at the picture "The Young Man of Nain." (Heinz H., age 14.)

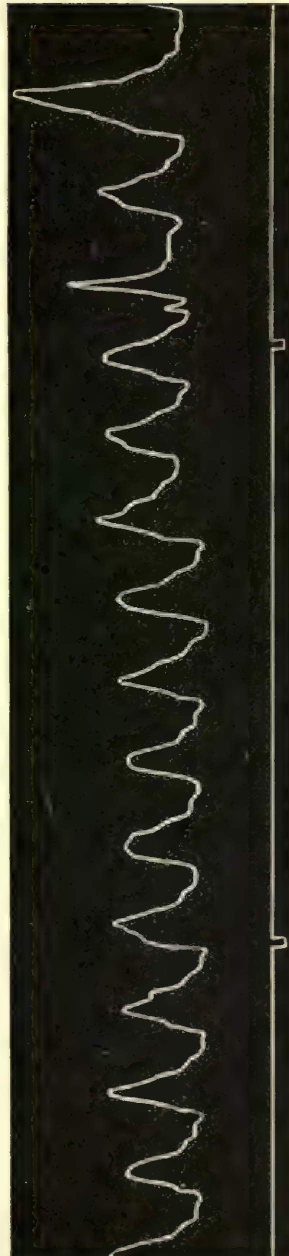


FIG. 72.—Breathing curve while looking at the picture "The Young Man of Nain." (Richard O., age 12.)

objective criterion. For such an investigation the expression method is exactly suited.

I recorded the breathing and pulse of a fourteen-year-old boy and showed him at the same time a picture. Fig. 68 shows the arrangement of the experiment. The boy is sitting behind a cardboard screen which has an opening at the end facing him. When this is opened or closed an electric contact is pressed. This closes the circuit

FIG. 73.—" Abraham and Lot."

(Voigtländer, Leipzig.)

and a small electro-magnet with a writing-point makes a mark on the drum of a kymograph. Fig. 69 shows the apparatus, above the tambour for recording the breathing, below that for the pulse and in the middle the small electro-magnet.

Let us now examine the changes of pulse and breathing when the picture appeared (Fig. 71), " The Young Man of Nain " (Fig. 70). The first mark on the middle line denotes that the picture is visible to the observer. The pulse curve (the lower one) at the same moment rises

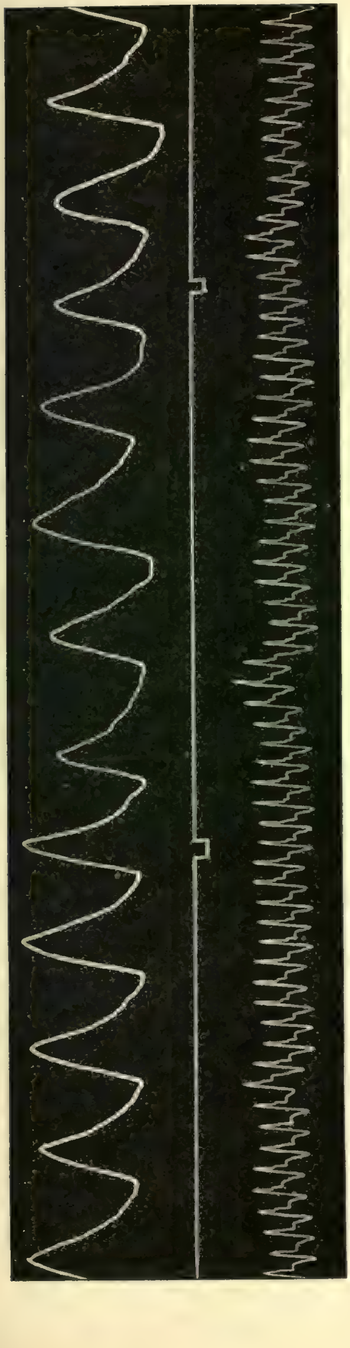


FIG. 74.—Breathing and pulse curves while looking at the picture "Abraham and Lot." (Heinz H., age 14.)

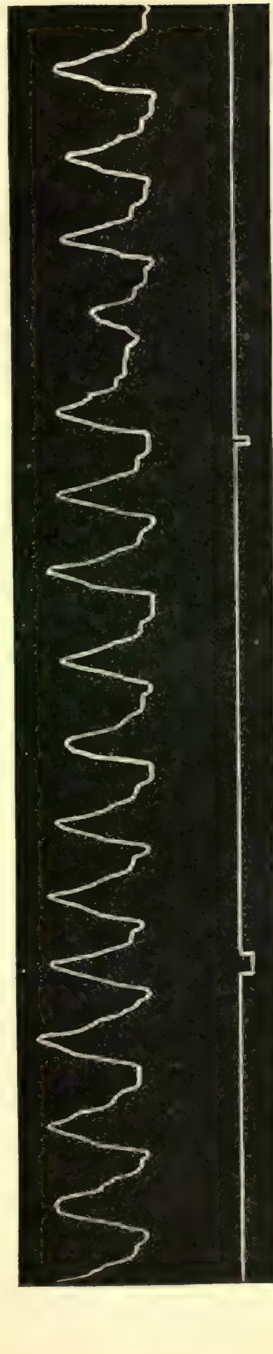


FIG. 75.—Breathing curve while looking at the picture "Abraham and Lot." (Richard O., age 12.)

with one leap very high; when the opening is shut and the picture no longer visible (the second mark on the middle line), the pulse sinks almost as rapidly. At each opening and shutting there seems to be an involuntary jerky movement of the hand. We see this in the other curve of the picture, "Storm on the Sea of Galilee" (Curve 77), but not in "Abraham and Lot" (Curve 74).

The pulse in Fig. 71, apart from this great displace-

FIG. 76.—"The Storm on the Sea of Galilee."

(Voigtländer, Leipzig.)

ment, does not seem to show any essential changes. At least I would not dare to draw any further conclusions from a curve of such irregularity.

On the other hand the change in breathing is quite remarkable (upper curve). Up to the opening regular breathing, then superficial, irregular breaths, and then, as soon as the picture vanishes, two deep breaths. The deep breaths at the end appear characteristic. We see them also in the curve of a twelve-year-old boy (Fig. 72).

The effect of the picture, "Abraham and Lot," is

quite different (Fig. 74). Breathing and pulse continue quietly and evenly as before. There is no trace of a great displacement of the pulse, no trace of a deeper breathing, either with the fourteen-year-old or the twelve-year-old boy (Fig. 75).

"The Storm on the Sea of Galilee" gave irregular breathing and unsteadiness of the pulse. Whether deep breathing followed, I could unfortunately not establish, as the available space on the drum came suddenly to an end. It is worthy of note, however, that the pulse is

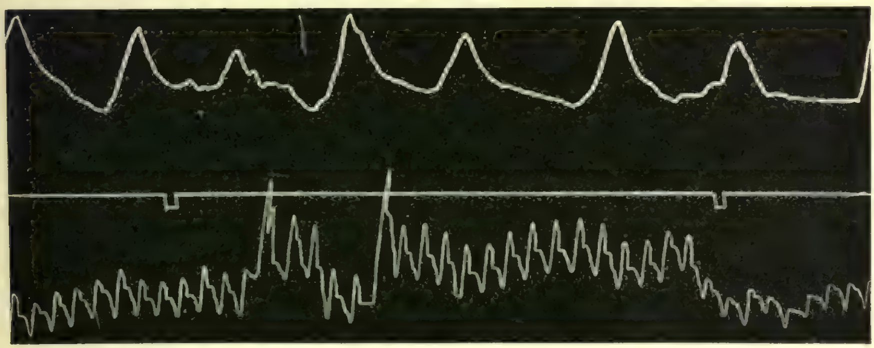


FIG. 77.—Breathing and pulse curves while looking at the picture "The Storm on the Sea of Galilee." (Heinz H., age 14.)

stronger during the inspection of the picture than before. A strong pulse is, according to Wundt, a sign of excitement.

Now I am ready to believe the boy, if he tells me that "The Storm on the Sea of Galilee" was the picture that excited him most of all. Without the objective proof with the pulse, I would have attached very little value to his statement.

On the basis of the curves obtained, and taking into account the statements of the boy, I would now venture to make the statement that the three pictures excited feelings in the boy, strong feelings of quite differing

Fig. 78.—Investigation of the pulse and breathing during stimulation of the sense of taste.

characters. To analyse these feelings more accurately would be the problem of a more thorough investigation. It would be interesting to investigate whether the pictures in our schools would similarly affect the pulse and breathing.

The investigation of children with the help of the expression method promises not only for pedagogy but for psychology important results, since it is to be expected that children will react more naturally and more vivaciously to certain simple feelings than adults will.

It is difficult with adults to obtain expression symptoms of pleasure after stimulation with a sweet taste, for the

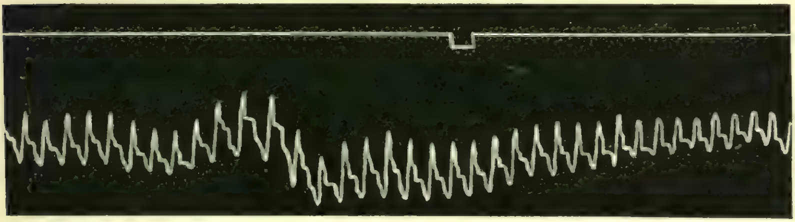


FIG. 79.—Pulse changes while tasting aloe. (Heinz H., age 14.)

simple reason that a sweet taste with many people does not cause a feeling of pleasure. I obtained, in the experiment mentioned at the beginning of the book, negative results from three out of five observers. These were the answers after stimulation with sugar:—A. "Fairly pleasant, then too sweet;" B. "A real feeling of pleasure has not arisen;" C. "This kind of sweetness is really unpleasant to me." With children, especially with girls, better results are to be expected. Fig. 78 shows the arrangement for such taste experiments. The boy receives a few drops of a liquid on his tongue. At the same time pulse and breathing curves are taken.

The bitter substance, aloe, causes a drastic change in the pulse curve (Fig. 79). The moment the stimulus

works, which is recorded by the mark on the upper line, the pulse becomes smaller and quicker, just as Wundt's theory requires for unpleasant feelings.

The effect of sugar (Fig. 80) is less marked. Only in the latter part of the experiment does the pulse increase. We note no slowing down of the pulse. Here it would be advisable to make experiments with girls.

The expression method not only serves as an index for feelings that are present, but may also in certain cases help to verify our introspection. Let me give an example. Many defective children show a preference for obnoxious smells. They maintain that these smells are pleasant.

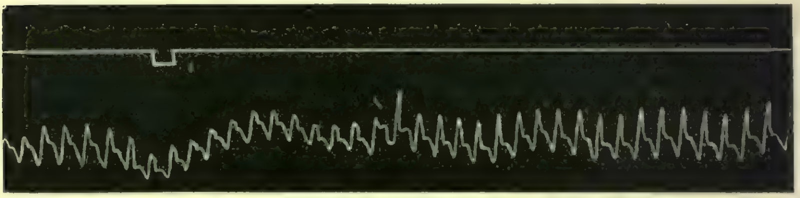


FIG. 80.—Pulse changes while tasting sugar. (Heinz H., age 14.)

It may be possible that in such a case a defect in the sense of smell is present, and that the specific quality of such a smell does not really come to sensation. If, however, the expression method shows us that the characteristic symptoms of pleasure are really present in such cases, then the statement of the child is verified. We then know that there is some radical defect in the child's feelings, and he should be sent to some home for special treatment.

II. THE INVESTIGATION OF THE SYMPTOMS OF OUTWARD EXPRESSION

1. The Investigation of the Pulse

We must now describe in detail the apparatus, which is used in psychology for investigating the pulse. The

medical practitioner makes use of many methods, inspection of the pulse by observing those places where the pulse can be seen beating, palpation, *i.e.* feeling the pulse, especially the so-called radial pulse at the wrist, auscultation, *i.e.* listening to the pulse beat, especially of the heart. All these methods are too rough and ready for psychology, because it has to take note of much finer differences than the medical man has. It is therefore necessary to have a written record of the pulse, so that we may accurately investigate all its characteristics. We need, therefore, a graphic method.

(a) *Pressure.*

An apparatus that gives a written record of the pulse is called a sphygmograph.

If we cross one leg over the other we notice that the upper leg moves up and down, following the rhythm of the pulse. A great pressure is exerted on the artery in the hollow of the knee. When a new wave of blood comes, it meets this impediment, forces its way through, and thus forces the leg slightly upwards. If I were to let a piece of smoked paper move along just touching my toe, the foot would record the movements of the pulse on this paper. We would get more accurate results, if we were to attach (say in the region of the heart) an easily movable lever (made out of a reed or piece of straw) with another lever (the writing-point) so lengthened that the smallest movement of the heart would be registered on a larger scale.

It will be much more convenient if we can separate the apparatus that receives the pulse beats, which must of course rest on the pulse, from the apparatus that writes them down. Such a sphygmograph is shown in Fig. 81. A support is fixed on the wrist with rubber bands. In the

middle of this support is a flat hollow capsule of metal, across which on the under side a fine piece of rubber is drawn. On this rubber a thin sheet of tin is fastened by means of sealing-wax, and in the middle of this there is a small wooden button, the pelotte (P). I move the capsule

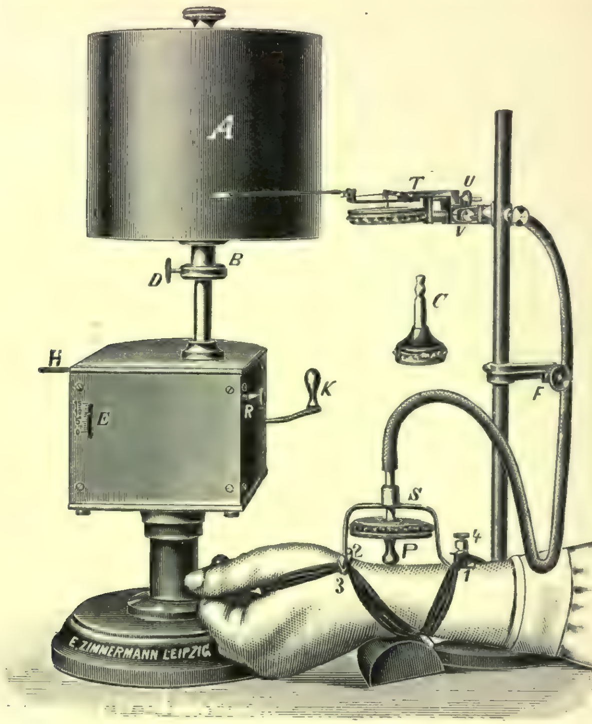
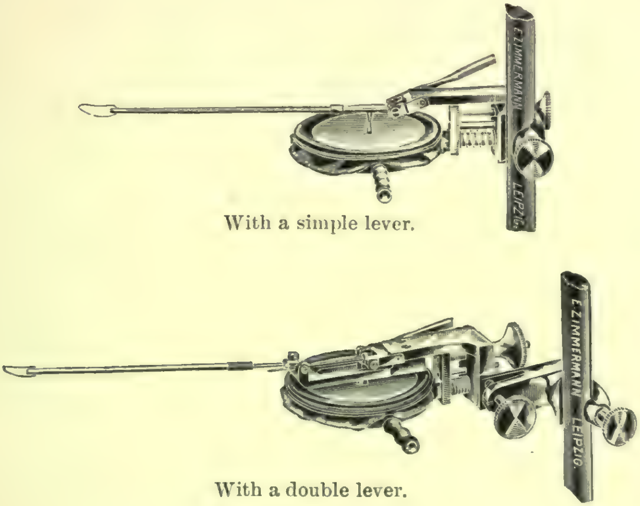


FIG. 81.—Kymograph and apparatus for recording the pulse.

down until the pelotte just touches the pulse. Every beat of the pulse pushes the pelotte and the thin piece of tin upwards into the capsule, the rubber, of course, offering scarcely any resistance. When the pulse sinks, the pelotte sinks as well. The air in the capsule will be compressed at each rise of the pelotte. These air waves are conducted along a rubber tube into the writing appa-

ratus (T), the so-called Marey tambour, which is just such another capsule, but this time the rubber is stretched across the upper side. In the middle there is a small vertical point, upon which a steel needle rests. This needle moves with every movement of the pulse. To enlarge the movements, another lever is fastened at the end of the needle. This is a steel needle bent in an upward direction. At the end of this there is a writing-



With a simple lever.

With a double lever.

FIG. 82.—Marey tambour.

point (A). Compare also Fig. 82. The movements of the pulse are thus enlarged fifty to eighty times. A well-recorded pulse is about 1 cm. high. To the left of the hand in Fig. 81 we see the so-called kymograph, the wave-writer. It consists of a clockwork, that sets a big drum in motion. Before the experiment the drum is detached and covered with a glossy piece of paper. It is well to damp the paper on the inside so that it may lie smoothly on the drum. The paper is then smoked by holding the drum over a petroleum-lamp and by turning

it slowly (Fig. 83). Then the drum is put into place, the screw (V) turned until the writing-point just touches the

FIG. 83.—Smoking the drum.

paper, and the clockwork is set in motion. The writing-point now records the pulse curve. When the paper is covered with records, we take it carefully off the drum, cutting it at the place where it is fastened together. We

dip it into a solution of shellac in alcohol, such as is used to fix carbon drawings, and let it dry (Fig. 84). Thus we

FIG. 84.—Fixing and drying the curves.

can preserve our curves for later study. To measure the curves we make use of a glass measure divided up into millimetres (Fig. 85).

The form of the receiving apparatus will, of course,

vary according to the part of the body we are investigating. To investigate the carotid, the large artery in the neck, we

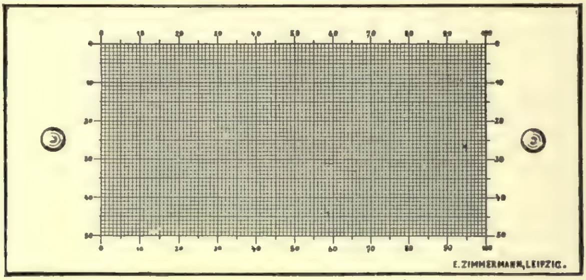


Fig. 85.—Glass plate with millimetre scale for measuring the curves.

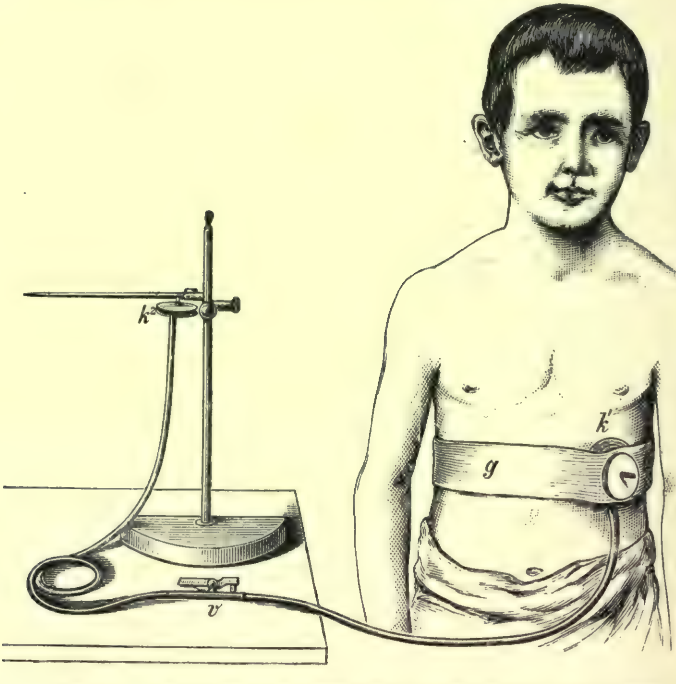


Fig. 86.—Cardiograph for investigating the beating of the heart. (From Langendorff, *Physiologische Graphik*).

make use of the carotid capsule (Fig. 81, C), which is a

hollow funnel-shaped capsule, on the same principle as the other, but without a pelotte in the middle. We press this against the carotid, keeping our elbow on the table in order to hold the apparatus quietly. The carotid capsule is convenient for purposes of demonstration, but is not to be recommended for exact investigations, as it is very difficult to hold the apparatus quietly enough for these purposes.

Fig. 86 shows the arrangement for recording the palpitation of the heart. Fig. 87 shows the cardiograph

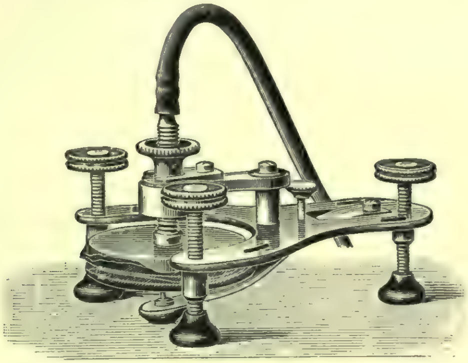


FIG. 87.—Cardiograph.

that is used. We note a similar metal capsule with pelotte as in the sphygmograph. The support has three feet that can be screwed up or down, so that it may be placed in proper position on the body.

(b) *Volume.*

With the apparatus described above the movements of the pulse were measured in this manner, and the changing pressure at a certain point of an artery was recorded. We might take another kind of measurement. A measurement of the amount of in-flowing and out-flowing blood.

A whole member of the body (say the arm) is put into a rubber sleeve and then into some special kind of jar. When this is filled with water, the rubber presses tightly

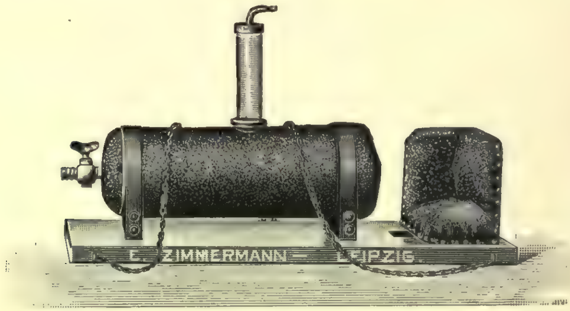


FIG. 88.—Plethysmograph.

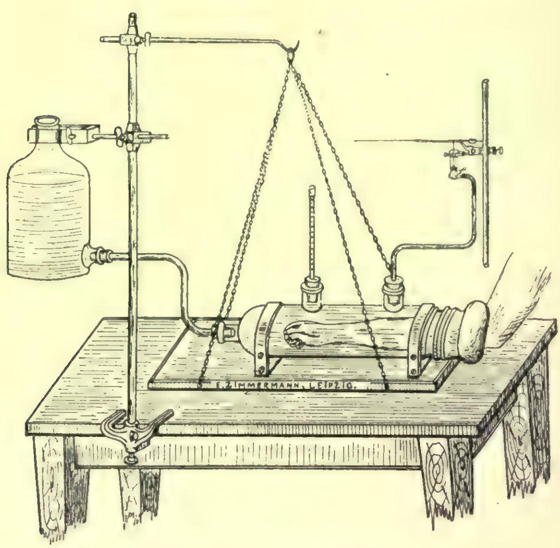


FIG. 89.—Plethysmograph.

on to the arm. The glass tube is then half-filled with water (Fig. 88). Now according as the blood flows in or out of the arm, the volume of the arm is slightly increased or diminished. The water in the glass tube rises or falls

accordingly. This apparatus is called a plethysmograph (a volume-writer). We can connect by means of a rubber tube with a writing-point, just as with the sphygmograph, and so get a record for the volume pulse (Fig. 89).

For many reasons, which need not be mentioned here, it is preferable in experimenting with children to use the sphygmograph.

2. The Investigation of the Breathing

Far easier and simpler is the investigation of the breathing. The first experiments with the pulse often turn out very unsatisfactory. It often requires half-an-hour before one can get a useful pulse record. In investigating the breathing the technicalities are very simple. The pneumograph is a simple flat rubber capsule with a tube at one end. This is tied on to the breast by means of a bandage, high up or lower down according as we wish to investigate the thoracic or abdominal breathing. It is best to test both at once. When the chest expands in breathing, the rubber ball is compressed. The pneumograph is connected with a writing-point, which is exactly the same as for a sphygmograph, except that here only one needle is necessary, since the movements of the pneumograph are naturally more extensive than those of the syhygmograph. For demonstration purposes an extra long straw may be attached (40 cm.), as in Fig. 90. We see here also how strong the movements are during mental work. We find similar movements during intense attention, say listening to the weak ticking of a watch. Especially in investigating the attention, breathing records ought to lead to important results.

In exact experiments the writing-point should be of the ordinary length. It is necessary also, in investigating either the pulse or the breathing, to be quite familiar with

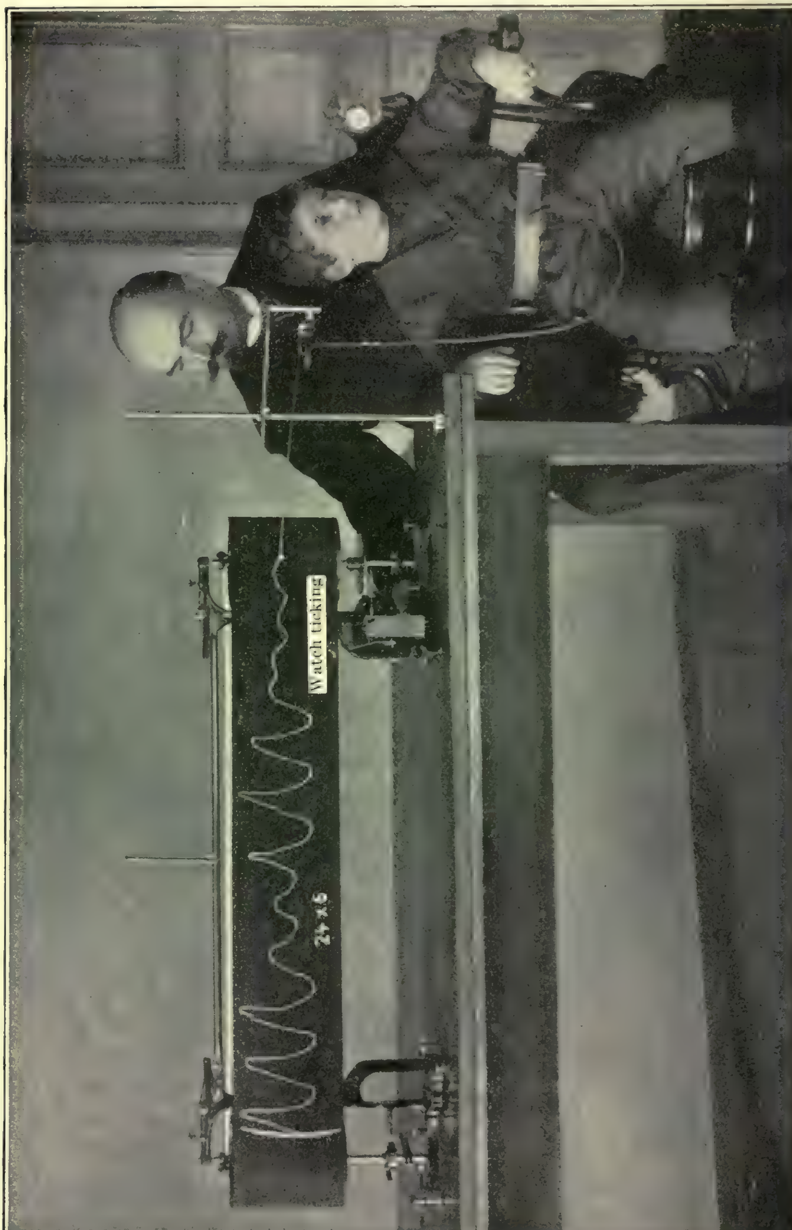


FIG. 90.—Demonstration of the breathing curve.

the physiological conditions of the pulse and the breathing.[1]

In putting the sphygmograph or the pneumograph into place, there always arises a strong pressure in the capsule which must be got rid of, or else the writing-point will remain pointing upward. To effect this there is a valve in the rubber tube connecting the receiving with the recording apparatus. This valve can be seen in Fig. 90 at about the same height as the watch. This valve is kept open until the apparatus is in place, so that there may be no pressure in the receiving or recording apparatus. It sometimes happens during the experiments, owing to some movement of the observer, that an extra positive or negative pressure arises, causing the writing-point to rise too high or sink too low. This is rectified by opening the valve.

Both pulse and breathing experiments have their advantages and disadvantages. Breathing records are easy to obtain, but the movements of breathing are to a certain extent dependent upon the will. If the child notices what is wanted, he may consciously or unconsciously spoil our results. I have generally tried to avoid this difficulty by employing the method without previous knowledge. For example, I say to the child, after fastening on the pneumograph, "I am going to try two things. First I will get a record of your breathing and then we shall examine a picture together." In this way I changed from one to the other, of course taking a breathing curve when the child was engrossed in the picture. It is bad not to say anything about the apparatus to the child, for if you do not he will be distracted by trying to think what it is for. Such small deceptions often cause a lot of trouble, but they are absolutely necessary.

The movements of the pulse are not dependent upon

[1] See von Frey, *Die Untersuchung des Pulses.* Berlin, 1892.

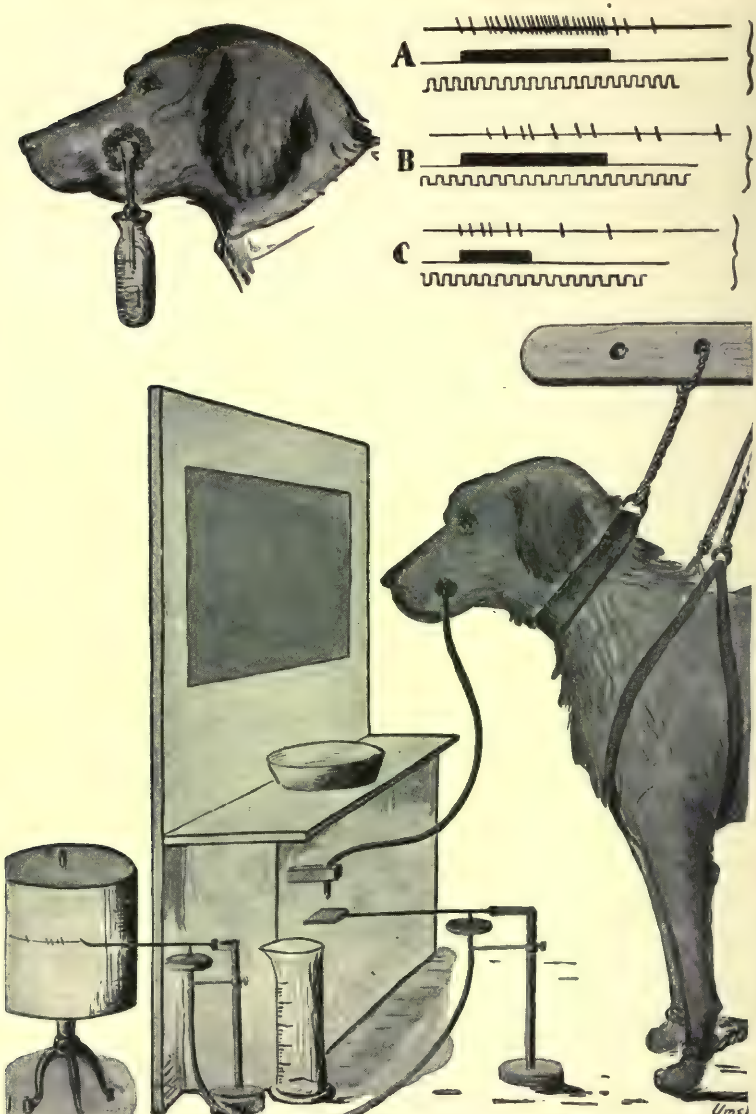


FIG. 91.—Pawloff's method of measuring the flow of saliva of the dog. Top, left: determination of the weight of the flow. Top, right: graphic record of the flow; A, at the word "Dinner"; B, at the sight of the food; C, at the sight of a red placard.

(From Claparède, *Umschau*, XII. 1908).

the will. But pulse records are technically much more difficult, and again the pulse is influenced by the breathing (whereas changes in the pulse only influence the breathing very slightly). It is therefore useful, in taking pulse records, to take records of the breathing at the same time. It is also desirable to take pulse records at different parts of the body at the same time.

The changes in secretion of the glands, especially of the salivary glands, have been used as expression symptoms most of all in animal psychology. If a hungry dog sees his food the saliva begins to flow. The amount of saliva produced can be measured (Fig. 91, top left); or by means of two capsules (as with the sphygmograph) each drop that falls is marked on a kymograph (Fig. 91). Fig. B shows the curve that results when the dog sees his food. The thick black line denotes the amount of saliva that dropped into the glass. The zig-zag line below is made by the apparatus marking the seconds. A dog may be accustomed always to get his food when he hears the word "dinner." If this is so, we find that an increased secretion of saliva takes place when the dog simply hears the word without seeing the food (Fig. A). A dog may also be accustomed to get his food after seeing a large red piece of paper. If it has become accustomed to this, the saliva begins to flow as soon as it sees the red paper (Fig. C). Such experiments have been carried out by the Russian scientist, Pawloff, and his pupils.

3. Pulse and Breathing Curves

An analysis of the pulse and breathing curves can deal with three things—the length, the height, and the form of the curve. Let us consider these characteristics for a pulse curve.

The length of the pulse denotes obviously the rapidity

of the palpitation of the heart. If I wish to measure it accurately I must have a time record underneath. For this purpose Jaquet's chronometer is suitable (Fig. 149). This consists of a very accurate clockwork, which is in connection with a lever with a writing-point, which gives an upward jerk every second, fifth of a second, &c., according as we adjust it. If I wish to make a more detailed study of the form of the curve, I make the kymograph revolve quicker, and fix the chronometer for a fifth of a second. Instead of Jaquet's chronometer I can also use the metronome used in our time experiments (Fig. 58). The negative wire and one or both of the positive wires are connected to an electro-magnet with a writing-point, the so-called recording-magnet. Fig. 92 shows Lombard's recording apparatus, and Fig. 93 an ordinary cheap recording magnet suitable for school purposes.

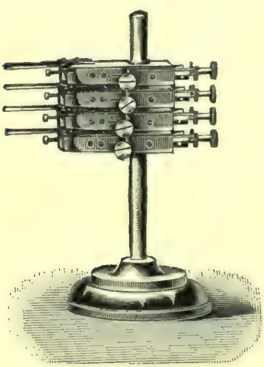


FIG. 92.
Lombard's recorder.

A study of the length of the pulse is to be greatly recommended. It is the characteristic which presents fewest difficulties in explanation.

The height of the pulse may arise from the strength of the beat of the heart. Or, secondly, it may be caused by an enlargement of the artery at the place tested. The walls of the arteries may become tighter or looser according to the condition of the blood or the activity of special nerve-centres. Now if the artery is not very tight the wave of blood will cause a stronger upward movement, and our record will show a higher mark. And, thirdly, there may occur in certain parts of the body (the abdominal cavity or the brain) a narrowing of the blood-

vessels from some cause or other. Less blood can therefore flow to these parts, and the blood-pressure at the places we are testing becomes stronger without the heart beating any stronger, and without any change arising at the places in question. And, fourthly, the height of the pulse changes considerably according as I fasten the sphygmograph tightly or loosely, according to the part of the artery that I touch.[1] The smallest change in the position of the arm often causes very considerable changes in the height of the pulse, as we shall see later in an example. We see, therefore, that we must draw our

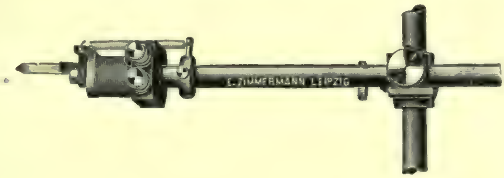


FIG. 93.—Ordinary recording magnet.

conclusions from the height of the pulse with the greatest caution.

The form of the pulse naturally differs according to the part of the body I test. Pulses that lie approximately the same distance from the heart are in general of the same form.

Each single pulse generally rises pretty abruptly, and then sinks slowly down (Fig. 94 *et seq.*). During the fall there generally appears a second (sometimes a third or even fourth) small rise, the so-called dicrotism. The normal pulse is dicrotic, a pulse with two beats, *i.e.* with two summits, the chief rise and the dicrotism during the fall. A probable explanation of dicrotism is the following.

[1] The tonograph is an apparatus for measuring the pulse, absolutely free from any objections. It consists of a small sharp tube that is introduced directly into the artery. This is only used in experiments on animals.

As soon as the blood streams into the aorta, this is in the neighbourhood of the heart enlarged on account of the sudden pressure, and this enlargement in the form of a blood wave is transplanted rapidly along the arteries. When it comes to the capillary vessels it cannot continue any further. These narrow vessels present an absolute impediment to the rapidly moving wave, which is thrown back, just as the waves of a lake are thrown back by the shore, even although there may be several small outlets at that part of the shore. The water flows slowly through these outlets (just as the blood does through the capillary vessels), but the more rapid movement of the waves is reflected backwards. This reflected wave appears as dicrotism, once, twice, or three times. If therefore in our pulse the dicrotism is a long way from the chief summit, then the rapidity of the wave is not so great. This may arise from one of two reasons. Either the beat of the heart is weak (the stronger the beat, the quicker the wave), or the walls of the arteries are loose. The tighter the walls are, the quicker the wave rushes along. If the walls were absolutely stiff, say of glass, then the wave would reach the capillary vessels at once. We see, therefore, that the changes in the form of a pulse curve do not lead us to absolutely unambiguous conclusions.[1]

[1] The same difficulties arise, if we wish to use the lateness of the pulse (how long it takes to come after the heart-beat) as an expression symptom. The pulse wave comes later the further away from the heart the artery is. Two different pulses can be recorded, say the radial pulse and the carotid pulse, and the difference in time fixed. From this we can reckon the rapidity of the pulse-wave, if we know the distance from the heart of the places tested.

To avoid the necessarily complicated calculations of such experiments, I propose the following method : Lead the tubes of both sphygmographs to the same tambour, which will now record both pulses. This will of course give a very complicated picture. If, however, a third tube open at the end is introduced into the tambour, each pulse will be recorded only by a very small rise. The distance can then be directly measured. (The open tube must be so long that the air waves only slowly flatten out, slowly enough to leave them sufficient strength to raise the writing-point slightly.)

Psychological analysis must therefore lay most importance upon the changes in the length of the pulse.

In Figs. 94–102 we see at the top the breathing curve, under this the time record (in seconds with the Jaquet

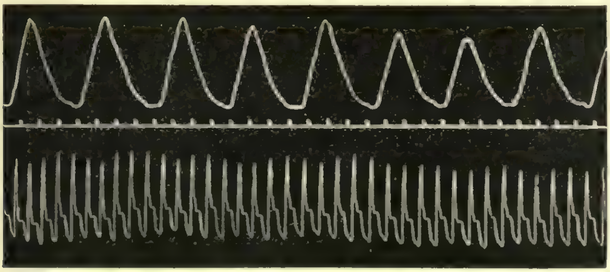


FIG. 94.—Normal curve.

chronometer), and at the bottom the pulse curve. These curves were taken during the experiment mentioned before, to test the effect of sweet and bitter substances.

Fig. 94 shows a normal curve—normal according to

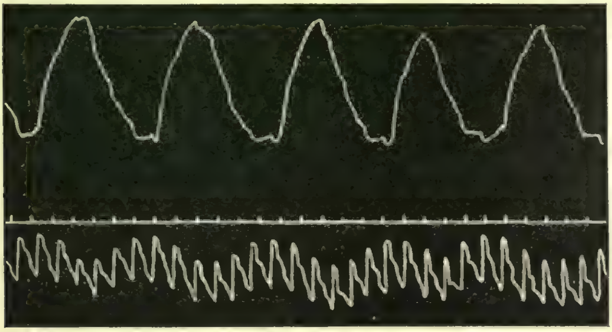


FIG. 95.—Normal curve. Traube-Hering waves.

the statement of the observer and according to what objectively can be seen (regular breathing and a regular pulse). The pulse recorder, owing to the strength of the pulse, "tossed" a little, and therefore the summits of the curve are a little too high.

In Fig. 95 we see how the pulse-wave as a whole

moves up and down, and we also notice that it follows the rhythm of the movements of the breathing. These Traube-Hering waves, so-called from the discoverers, probably arise from the condition of the blood (percentage of oxygen), by which certain nerve-centres are excited (the so-called vaso-motor centres), which cause a rhythmical change in the tension of the walls of the arteries. These so-called secondary waves (the separate pulse waves are the primary waves) have, therefore, no psychological meaning. They can easily be detected by their rhythmical progress, especially if we have a simultaneous curve of the breathing.

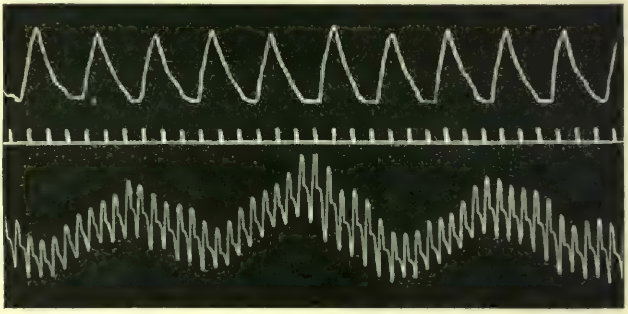


FIG. 96.—Normal curve. Mayer's waves.

In Fig. 96 we see still more extensive oscillations of the whole curve, and they last longer. They are the so-called Mayer waves, and their cause is not yet fully explained. If one notices such oscillations in a pulse curve, it is best to stop the experiment, since an explanation of such a curve is too difficult.

The curve in Fig. 97 begins with a high pulse which suddenly sinks down (because of a small movement of the observer), and the pulse rapidly decreases owing to this outside circumstance. In the middle of the curve it has sunk almost to zero. I then open the valve (twice in succession) and the writing-point jumps up and the pulse becomes almost as high as at the beginning.

Fig. 98 shows the different changes in the pulse that occur in different observers, if the breath is held. The

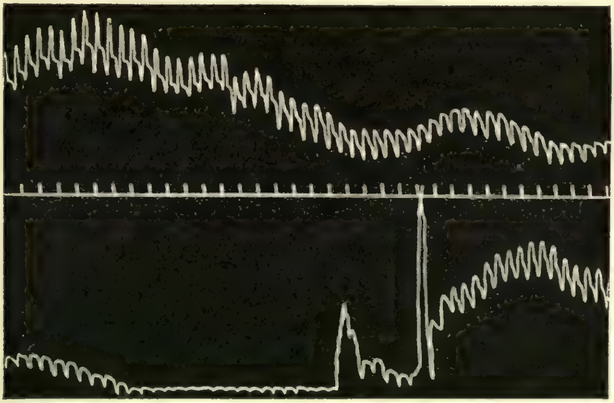


FIG. 97.—Normal curve. Dependence of the height of the pulse on the position of the writing-point.

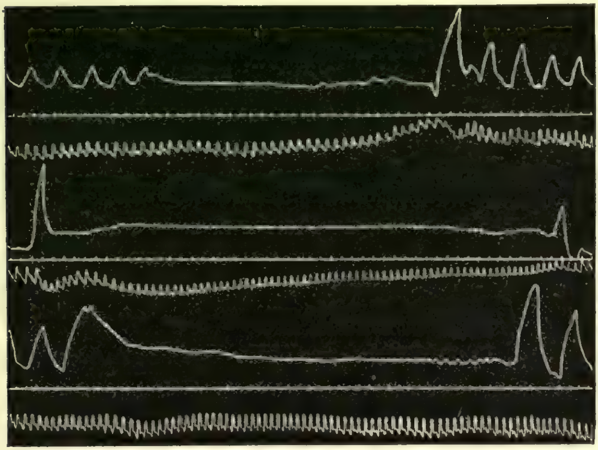


FIG. 98.—Holding back the breath and its influence on the pulse.

lowest curve shows scarcely any change. The second shows considerable changes in form, size, and length of pulse.

The upper curve in Fig. 99 was the first that I took

of the observer in question. It is a so-called normal curve, where no stimulus is at work. The curve shows in pulse and breathing very obvious irregularities. When I asked the observer to give me his experiences during this "normal" curve, I obtained the following answer: "It seemed as if I were at the dentist, who was standing behind me and getting ready to stop my teeth." The observer had before been present as an onlooker at experiments,

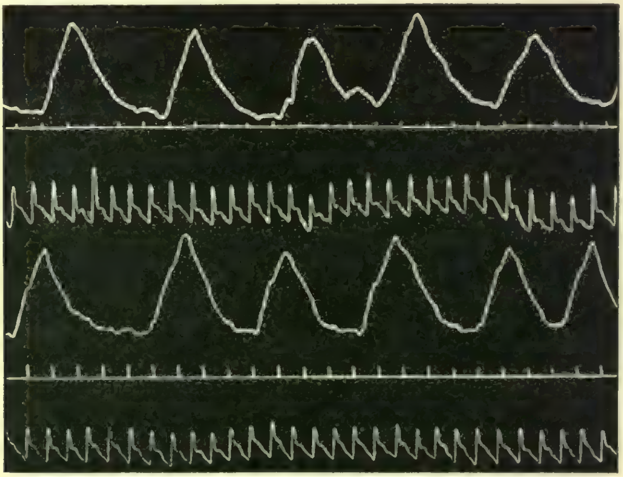


FIG. 99.—Normal curves.

where "fright" stimuli (say a sudden loud noise, smashing of glass, &c.) had been used. After I had assured the observer that I would give absolutely no stimulus, I obtained the second curve, which is quite normal.

In experimenting with children much greater care must be taken that they become familiar with the conditions of the experiment.

The first curve in Fig. 100 is a normal curve. The statement of the observer was, "I was dozing peacefully. I thought, how pleasant it is that it is so quiet here, and how quietly and subdued the clock ticks. In the middle

of the experiment I noticed a slight tugging at the heart." The quiet course of the pulse and breathing corresponds exactly to the introspection. The little disturbance at the heart can be clearly seen on the pulse curve.

Curve 2 is normal up to the middle. Then the observer received as stimulus, a solution of sugar. The breathing curve is immediately affected by the movements of swallowing. The observer's experience is, "From the

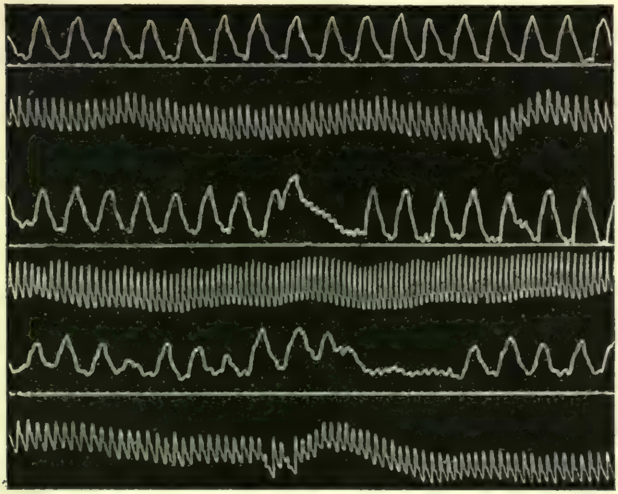


FIG. 100.—Taste experiments.
1. Normal curve. 2. Solution of sugar. 3. Vinegar.

very beginning my state of consciousness was different from that of the previous experiment, more restless, not so unrestrained. This increased at the signal, 'Now.'[1] A feeling of strain arose. A real feeling of pleasure did not arise. Perhaps I was disappointed at the slight effect of the stimulus. My state of consciousness then became gradually quieter."

In Curve 3 a solution of vinegar was given, again about the middle. Observer's statement, "Before the

[1] Such a signal was always given before applying the stimulus.

stimulus I felt a slight tendency to sneeze, which gave rise to a feeling of something comic. At the moment of the signal, 'Now,' this feeling disappeared entirely. The taste itself was rather refreshing and not unpleasant. Perhaps more pleasant than in the previous experiment. There my expectation seemed disappointed, here my expectation seemed relieved."

Here we have a case where a sensation of sweetness does not cause a feeling of pleasure, where there is, even with vinegar, only a slight change in feeling to be noted. Corresponding to this we note no essential change in the

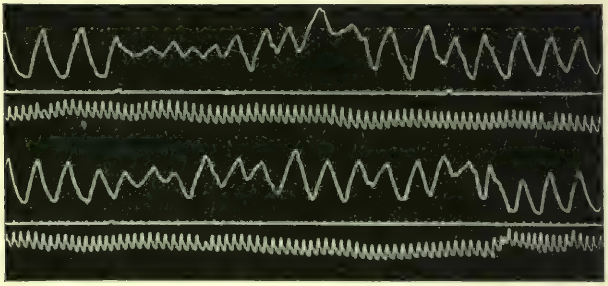


FIG. 101.—Attention. Counting the ticks of a watch.

pulse. On the other hand these experiments show how exact introspection often leads to very important side-results. The "restless" state of consciousness during the whole of the second experiment is clearly seen in the extraordinary rapidity of the pulse-movements. The change to a quiet state is shown in the slowing down of the pulse towards the end of the curve. We also see the effect of the comic feeling on the pulse in the third curve—two very irregular forms. The breathing, however, continues quite regularly. The sudden disappearance of the feeling is shown in the oscillation of the curve as a whole (Mayer's wave), which takes place before the stimulus is applied.

In the two curves in Fig. 101 the time-recorder shows

two marks. During this period the observer had to follow the weak ticking of a watch. We see how this state of attention shows itself, especially in the breathing curve.

Fig. 102 shows the pulse during mental work. At the

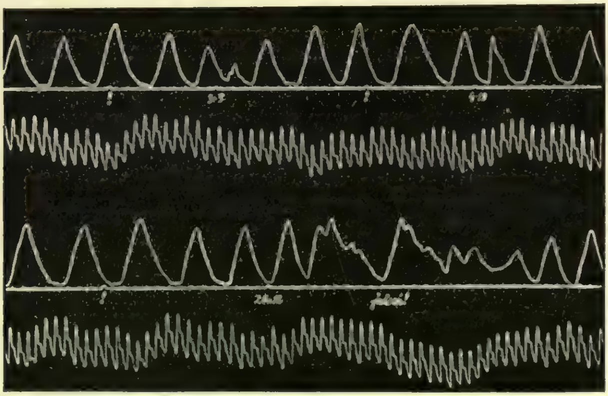


FIG. 102.—Reckoning.

word "Attention!" (!) we notice a lengthening in the breathing curve and a slight Mayer's wave in the pulse. This wave becomes more marked during the difficult task 28×12; and still more marked when I shouted "Wrong" (*falsch*), although the multiplication was

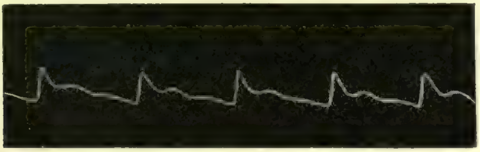


FIG. 103.—Pulse curve before a 200-metre race.

correct. The observer stated that "Wrong" caused a very unpleasant feeling, and he began intensely to work out the multiplication again, considering at the same time whether I had not misunderstood his result. That bodily exertion influences pulse and breathing is well known. Figs. 103 to 106 show this clearly. It is in-

teresting to note that the largest changes appear in people out of practice (compare Figs. 106 and 107). It would

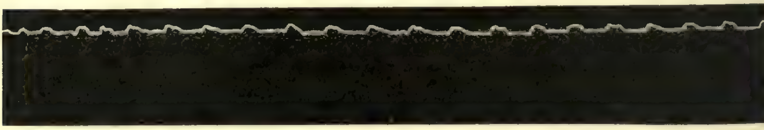


FIG. 104.—Pulse curve immediately after the race.

(From Schmidt, *Unser Körper.* Voigtländer.)

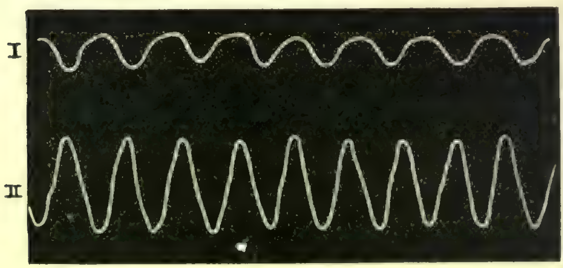
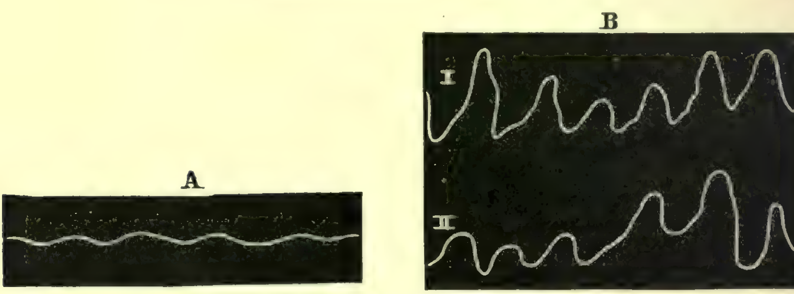


FIG. 105.—Breathing curves before and after a cycle run of about 20 km.

(From Schmidt, as in Fig. 104.)



FIGS. 106 and 107.—Breathing curves before and after a cycle run of a beginner.

Fig. 106. Before the start. Fig. 107. I. Loss of breath immediately after the run. II. 2 mins. 10 secs. later.

(From Tissie. *L'hygiène du velocipédiste.*)

be interesting to know in what state the pulse and breathing of our children is after the gymnastic lesson, and what differences the different systems of gymnastics cause.

It would be very important to test pupils (especially of higher schools) before and after an examination.

III. THE INVESTIGATION OF THE MOVEMENTS OF OUTWARD EXPRESSION

In investigating simple feelings it is best to make use of the symptoms of expression as we have shown. In investigating the emotions and moods we do well to include, for purposes of comparison, the changes in real movements of expression. Let us show by means of an example the methods we can make use of here. A few years ago the following question was vigorously discussed: "Are children capable of understanding and enjoying a work of art?" Let us try to answer this question.

1. Outward Expression by Speech

Speech, as is well known, arose out of movements of expression (interjections), and it can be called a system of expression movements, if we take the idea "expression movement" in its widest sense. Let us therefore use this means of expression in our investigation of the feelings. Let us show the child a picture and then ask him or her to make some statement about it.

After showing the picture in Fig. 108, I obtained the following accounts:—

Girl A. We see a beautiful meadow through which a violet river runs. On the left side of the river there stands a row of birch-trees. They have white barks. Behind is a forest. It will soon be summer, for the birches have green leaves, and the meadow looks already quite green.

B. On the side birch-trees stand, with white barks.

The beginning, where the leaves begin, looks red, the other green.

C. This is the foot of a hill, which goes high up. We can see this from the wood behind.

D. The river must be running quickly, because it tears a lot of the bank away.

E. It flows slowly, for its way is easy. Therefore there are such curves.

FIG. 108.—"The Valley," by Hein. (Teubner.)

F. If one looks at it from the side, one can see the river properly flowing.

G. The birches are placed nearly along the bank.

H. The meadows lie lower than I or the dam upon which the birches are standing.

I. The air seems to be clear.

K. The dark-green wood is thick. Not a bit of sky peeps through.

We see at once that this method is not suitable. As

soon as speech sways the course of associations, the feeling-element recedes. The children try to explain the objective content of the picture. Thoughts and judgments as to content appear. Of the effect on the feelings we learn nothing.[1]

We might learn more if we could manage to call forth interjections or exclamations. I managed this in regard

FIG. 109.—"Schiller," by Bauer. (Teubner.)

to the picture of Schiller (Fig. 109) by saying, "Look at this head very carefully. The mouth will soon open and begin to speak, just one short word." One of the pupils

[1] Perhaps we might get slightly better results if we permitted the children to speak in their own dialect or patois. Dialect expresses a man's inner feelings more accurately than the literary language. It gets nearer to him. This can be seen by asking the children to write down a sentence with a word that the teacher gives them. We change now from the literary language to the child's dialect and note the changes in the sentences *e.g.* (Cat) "The cat is a mammal." (Pussy) "Oh how the poor pussy miows! Are you hungry, pussy?"

immediately got up and exclaimed, "Ye miscreants, get ye gone! What do ye want with me?"[1]

2. Outward Expression by Drawing

The drawings of children, their expressions while drawing, might also be considered as a means of expression. We might tell them, after examining a landscape, to draw what they like, or to draw a figure that would suit the landscape. Children of the age with which I was experimenting (twelve-year-old girls) have not the courage to express themselves freely in their drawings I therefore chose the following indirect method.

I said to the children, "When I look at a landscape for a long time, something wonderful sometimes happens to me. A figure suddenly appears in it. Look at this picture for a long time, so long, until perhaps a figure will appear. Then describe to me as accurately as possible how it looks and what it is doing." The picture was "The Valley," by Hein (Fig. 108). The result was as follows:—

A. A little girl is sitting on the bank of the stream with a fishing-rod in her hand.

B. A little girl with a red dress and a red hood is sitting in the meadow and holds her head between her hands.

C. A mother is sitting with her girl and boy on the bank. The little boy is lying on his back, holding his hand in the water. The girl is also lying on the grass. The mother is sitting.

D. Through the avenue of birches a woman dressed in black is walking. She forms a great contrast to the white barks of the trees.

[1] The girl used in the original German such phrases as might easily appear, say in Schiller's "Robbers." She obviously felt that Schiller would use such expressions to the group of children crowding round his portrait.—*Translator's Note.*

E. On the left bank a girl is lying asleep. She has a green dress on. It matches the meadow.

F. On the bank of the stream near to the black bush a girl is standing looking into the water.

G. A boy is lying on the bank, his elbows on the ground and his head resting on his hands.

With the picture "Autumn," by Ortlieb (Fig. 110), I obtained the following results :—

A. On the hill a woman is standing, dressed in black.

FIG. 110.—"Autumn," by Ortlieb. (Teubner.)

B. I imagine a traveller dressed in black. He is standing at the fence at one side, leaning on the fence and looking at the road that disappears in the distance.

C. A woman dressed in black is leaning on the fence and looking at the dark fir-trees.

D. A woman dressed in black is standing on the road.

Both in the colour and the pose of the figures described, we see clearly that the mood of the child corresponds to the mood suggested in the picture.[1]

[1] For a full account of these experiments, see *Bilderbetrachtungen, Arbeiten aus der Abteilung für Kunstpflege des Leipziger Lehrervereins.* B. G. Teubner, Leipzig, 1906.

This method has proved itself better than the other, even although it appears complicated.

3. Outward Expression by Mimicry

I have often watched the mimicry of children (*i.e.* the changes in the muscles of the face), when I have shown them a picture for the first time.[1] If we wish to analyse these movements it is necessary, for the purposes of later study, to fix them in some way. The special apparatus, which is used for recording the changes in the facial muscles, is here of no use. We shall describe it, therefore, when we deal with the mimicry of attention.

I chose therefore another method, the photographic one, which up till now had only been used in investigations on the insane. I showed the children a picture and photographed them at the same moment.

By this method we certainly do not fix the whole course of the feeling but only a section of it. Nevertheless such photographs give us sufficient material for comparison.

Figs. 114–125 show the same child in front of all the pictures that were shown—a scale of affective processes reaching from unrestrained merriment down to the deepest earnestness. It is worthy of note that this girl, who was not one of the best in the class, reacted most sensitively to the more difficult moods. She was a year older than her school-comrades.

[1] How capable of expression children's faces are, is seen in Figs. 111–113. The children are tasting sugar, lemon, and aloe respectively. Note the turning up of the eyes of all three children when tasting a sweet substance, the same as with an infant sucking milk. I had hoped to find again the "sweet," "sour," and "bitter" expressions in looking at pictures, and so receive some help in an analysis of the feelings. This only happened with "sweet." At the "sweetest" of the twelve pictures ("A Wealth of Flowers," by Biese) the same expression of the mouth appeared. Perhaps I gave too strong solutions of sour and bitter.

For a fuller description of these experiments, see R. Schulze, *Die Mimik der Kinder beim künstlerischen Geniessen.* Voigtländer, Leipzig.

FIG. 111.—A sweet taste—sugar.

FIG. 112.—A sour taste—lemon.

FIG. 113.—A bitter taste—aloe.

FIG. 126.

FIG. 114.

FIG. 115.

FIG. 116.

FIG. 117.

FIG. 118.

FIG. 119.

FIG. 127.—"The Insatiables."

FIG. 120.

FIG. 121.

FIG. 122.

FIG. 123.

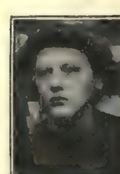


FIG. 124.

FIG 125.

FIGS. 114–127.—What feelings do the children show? Answer (Observer A): "The fact that the children's faces make me laugh, makes it pretty clear. They show unrestrained laughter and joy. The subject of the picture lies within the children's circle of ideas. It must represent things well known to them. The older girl in the middle restrains herself a little. She seems to say to herself, 'This is too childish for you.' Perhaps it is one of Caspari's pictures." When the twelve pictures were shown, Caspari's "The Insatiables" was at once chosen as the one corresponding to the photograph.

FIG. 128.

FIG. 129.—"The Crucified Christ."

FIG. 128–131.—What feelings do the children show? Answer (Observer A): "It is the direct opposite of the last picture ("The Insatiables"). A little of the previous amusement is still reflected in their faces, but the children restrain it." What do you mean by the direct opposite? "Perhaps it has something to do with a biblical story. Perhaps angels are on the picture. Certainly something religious."—What picture might it be? "The subject is not a childish one like 'Christmas Eve.' Perhaps it is 'The Resurrection.' The seriousness shown has something conventional about it." When the pictures were shown, the right picture, "The Crucified Christ," was chosen.

Observer B: "The great change in the feelings shows that something exceedingly serious has fully obliterated the previous impression. Some dying or ill person or something very sad." When shown, "The Crucified Christ" was chosen.

Observer C: "A picture, very likely a religious one, full of feeling. Quite a contrast to the previous picture. The positions of the hands and bodies are interesting, especially of the girl at the right. Her eyes are turned upwards. All are affected in the same degree." When shown, "The Crucified Christ" was chosen.

Fig. 126 shows a larger number of pupils looking at the picture shown in Fig. 127. Fig. 128 shows the same children looking at the picture "The Crucified Christ" (Fig. 129).[1] These were the first pictures which I showed the children. The difference in the expression of the children cannot be mistaken. Now we must find out how

FIG. 130.

FIG. 131.

accurately the expression corresponds to the feeling-tone of the picture.

To test this I showed the twelve photographs of the children to four persons, a lady, a scholar, an artist, and a teacher, and told them to describe the feelings of the children and to give some idea as to the picture that would correspond to such feelings. Under the Figs. 126 and 128 some of these judgments are printed. It is astonishing with what degree of certainty observer A, for example, describes the picture, and with Fig. 126 guesses even the painter, without knowing that one of Caspari's pictures was among the twelve.

Then I showed the observers the twelve pictures and asked them to find the photograph of the children that corresponded to each picture. Observer A accomplished

[1] Figs. 130 and 131 are taken from Duchenne's book—*Mécanisme de la physiognomie humaine*. Duchenne stimulated the muscles of the face with an electric current to show what muscles took part in certain feelings. Figs. 130 and 131 reproduced an expression of religious feeling. The second girl in Fig. 128 shows exactly the same expression as the head in Fig. 130.

this without one mistake, the other observers made only a few slight mistakes.

Our first experiment is the more important of the two. Out of an analysis of the observers' judgments we must find what feelings can be gathered out of the faces of the children.

4. Outward Expression by Pantomime

It had not been my intention in these experiments to investigate the pantomimic movements, *i.e.* the movements of the whole body and its members. By a lucky chance the photographs also included the hands of the children. I was very much astonished to find here, as well, quite a number of signs as to the feelings of the children.

Strong excitement shows itself clearly in the tense upright position of the body, in the clenching of the fists or in rubbing the right thumb strongly. A quieting feeling shows itself in a sinking together of the body, a slight spreading out of the hands or touching softly with the finger-tips.

We see in Fig. 132 a picture of joyful excitement—the clenched fist, the body held straight up, the mouth slightly open and drawn tight (Fig. 136 shows the picture that corresponds to the photograph.)

The limp body, the groping fingers and the laughing mouth in Fig. 133 show cheerful quietness. (An Alpine valley in lovely colouring was the corresponding picture.)

Fig. 134 shows serious quietness; the body is sunk together, the hands are lying loosely together, the mouth is normal and the brows are drawn together (Fig. 137 was the corresponding picture).

Fig. 135 shows serious excitement. The body is held

straight up, the thumb is rubbed strongly, and the brows are drawn tightly together (Fig. 138 was the corresponding picture).

Figs. 134 and 135 are of special importance. Both times landscapes were shown, each of a serious nature. The exciting element in the picture of a thunderstorm, and the quieting element in that of the moonlight—both are clearly shown in the expression of the child's face.

FIGS. 132–135.—Pantomimic expression movements while looking at pictures.

(From *Neue Bahnen*. Voigtländer.)

That hands can also speak, we see from examining Figs. 139 to 143. They tell us about the inner feelings of their possessor. Figs. 139 and 143 show a comfortable groping about with the finger-tips, a pleasant enjoyment. (The Alpine valley was the picture corresponding to Fig. 139, and a shepherd with his flock to Fig. 143.)

How different are the hands in Figs. 141 and 142! What energy is shown in the clenched fist or in the strong rubbing of the right thumb! In Fig. 141 the hands of the third scholar cannot be seen. She has raised them and crossed them over her breast. These are pictures of

great excitement, serious in Fig. 141 ("The Dawn," Haug's well-known picture out of the period of the Napoleonic wars) and joyful in Fig. 142 ("The Goblin," Fig. 136).

FIG. 136.—"The Goblin." (Voigtländer.)

FIG. 137.—"When the Moon rises," by Graf Freiburg. (Voigtländer.)

FIG. 138.—"Poplars in a Storm," by Kampmann. (Voigtländer.)

Fig. 140 shows the exact opposite. The hands lie loosely together. A perfect calmness. (The picture was "When the Moon rises," Fig. 137.)

FIG. 139.

FIG. 140.

FIG. 141

FIG. 142.

FIG. 143.

FIG. 139–143.—Speaking hands.

(From *Neue Bahnen*. Voigtländer.)

Whoever now puts the question, as to whether children really understand pictures, will surely be able to answer it.

CHAPTER V

THE WILL

I. THE TIME ERROR IN ASTRONOMICAL OBSERVATIONS

1. Astronomical Methods of Time Measurement

The director of Greenwich Observatory, the astronomer Maskelyne, noted in the publications of the Observatory in 1795 that he had been forced to dismiss his assistant, Kinnebrook, because he had accustomed himself to a false method in observation. Kinnebrook always observed the stars half a second or a whole second later than the director of the Observatory. The honour of the unfortunate assistant was saved many years later by the German astronomer Bessel, who established, by comparative observations, that the records of any two observers never exactly corresponded. Each observer differs from any other in a certain manner, so that all his observations differ from those of a second by a certain amount. These phenomena Bessel classed under the name of "the personal equation," without being able to give any explanation.

The method of the astronomers was the so-called "eye and ear" method. The observer directs his telescope to a certain part of the heavens where the transit of a star is expected, and observes its entrance into the field of vision of the telescope and its passing a thread that is stretched across the middle of the field of vision. At the same time he listens to a clock that strikes the seconds and he then determines at what stroke the transit takes

place, or at what distance from the thread a certain stroke of the clock was to be heard.

To get rid of "the personal equation" another method was introduced, the "eye and hand" method. The observation through the telescope was the same, but the striking of the clock was abolished. Instead of this the observer pressed down a tapping-key and let go at the moment the transit occurred. The letting-go of the tapping-key set a recording-magnet by means of electricity in action, and the writing-point of this magnet at the same moment made a mark on a small moving strip of paper. On the same paper seconds were marked by another magnet which was connected with an accurate clock. The precise time when the tapping-key had been released could be now read off. At this moment the observer had seen the star passing the thread.

But even with this method, which is used in our observatories to-day, the "personal equation" still remained, and it was left for experimental psychology to explain the cause of this phenomenon.

2. The Transit of a Star

In order to test the processes that occur in astronomical observation, let us try to observe the transit of a star by means of some simple apparatus.

In Fig. 144 we see the kymograph, which we have already used in recording pulse curves. It can be strongly recommended because it is both cheap and convenient (it can be placed horizontally or vertically). We see that on the axle, which comes out of the clockwork, a small wheel, the friction-wheel, is attached. When this turns, the round plate resting upon it, and therefore the drum, is set in motion. Now according as we place this friction-wheel near or far from the axle of the drum, the drum

turns more slowly or more quickly. We also see clearly in the figure the two contact-arrangements below on the axle. Each has a small vertical point. One of them is just touching a piece of brass, and so closes an electric

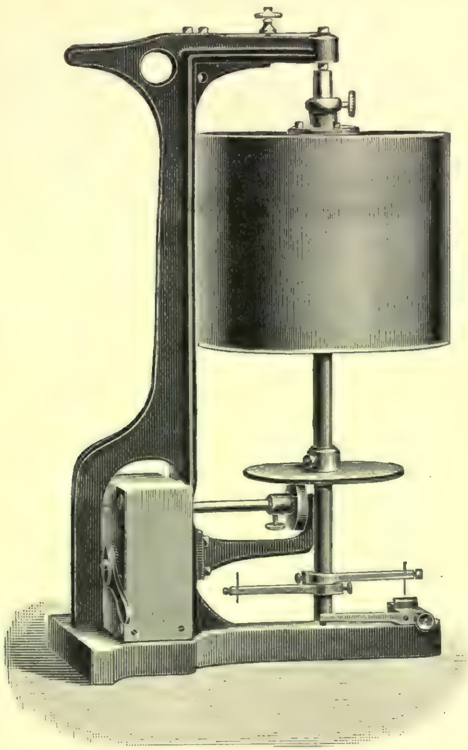


FIG. 141.—Kymograph with Clockwork.

(From *Petzold's Catalogue.*)

circuit, which goes from the little screw in the front, through the spring that is pressing against the axle of the drum at the bottom, through the contact-rod, the steel-point, the piece of brass, and a screw at the other side (not seen in the picture) from where it could be led further. As soon as the kymograph turns further round, the steel-

point moves off the piece of brass and the circuit is again broken.[1]

The speeds necessary for astronomical observations and for other psychological time measurements cannot be attained with such a simple instrument. More com-

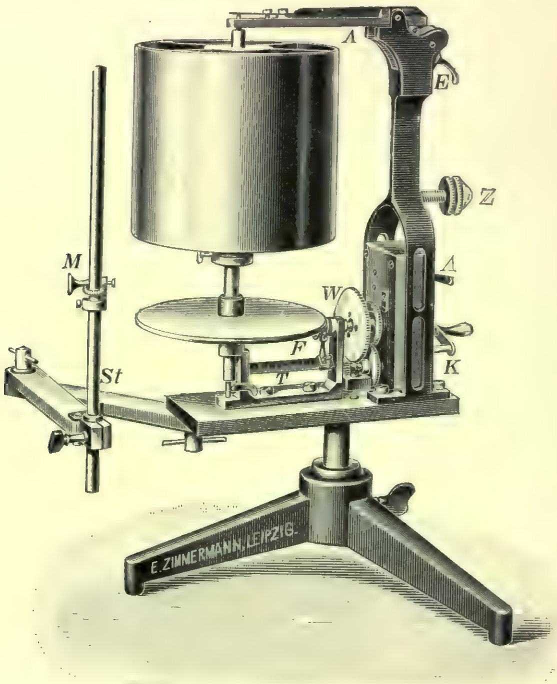


FIG. 145.—Kymograph.

plicated and therefore very expensive apparatus is required. I have therefore made a small change on the simple kymograph, by means of which a very quick and regular movement of the drum is achieved. The apparatus is so simple to manage that even the unskilled may obtain good results. Fig. 146 shows the improved

[1] The kymograph shown in Fig. 145 is one that is well suited for recording pulse and breathing curves (Chaps. IV., II.)

apparatus.[1] The spiral spring, S, is tightened by being placed in position against the bar of steel, W. If the lever F is pressed down the drum will make one revolution, and then be held again in the catch which the lever F has opened. If the lever is continuously held down the drum will continue to revolve. The roller R can be

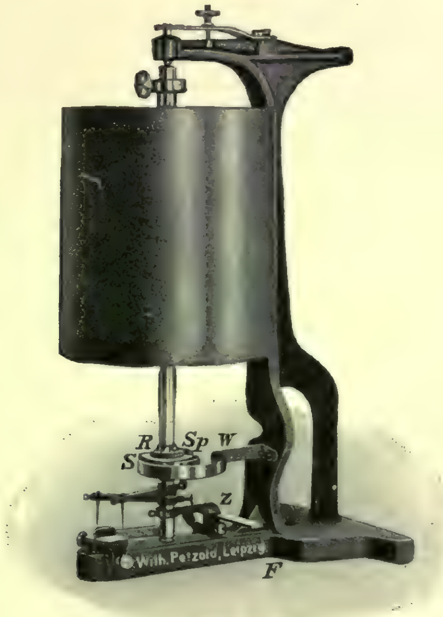


FIG. 146.—Spring kymograph.

turned round a ratchet-wheel, Sp, to tighten the spring. By this means the velocity of the drum may be regulated.

To test the velocity, we cover the drum with smoked paper (see p. 128), set it in motion, and let a long steel spring, to which a horse-hair has been attached, mark its oscillations thereon (Figs. 151 and 153 show such oscillations).

[1] The picture shows an apparatus without clockwork, friction-wheel, and friction-plate. These of course may still remain on the apparatus, so that both slow and quick speeds can be obtained.

These time tests are best taken before and after the experiments, so that the observer may not be disturbed in his observations by the noise of the spring.

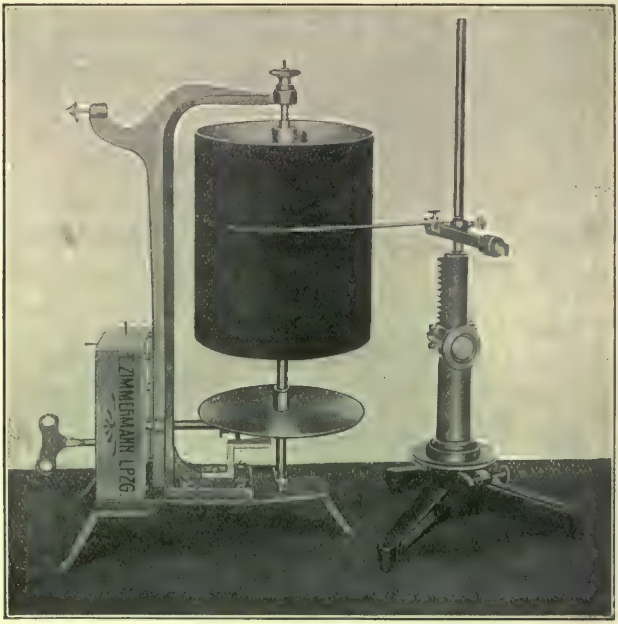


FIG. 147.—Ordinary recorder. ($\frac{1}{5}$ sec.).

A little electrical bell may also be used for recording time. Take away the bell and lengthen the clapper with

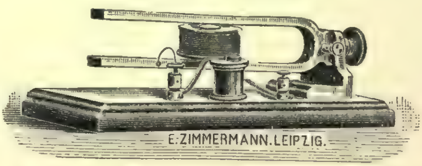


FIG. 148.—Electro-magnetic tuning-fork.

a long writing-point (Fig. 155 shows at the top such a writing-point and the curve drawn by it).

For accurate time measurements in scientific work electro-magnetic tuning-forks are used. Fig. 148 shows

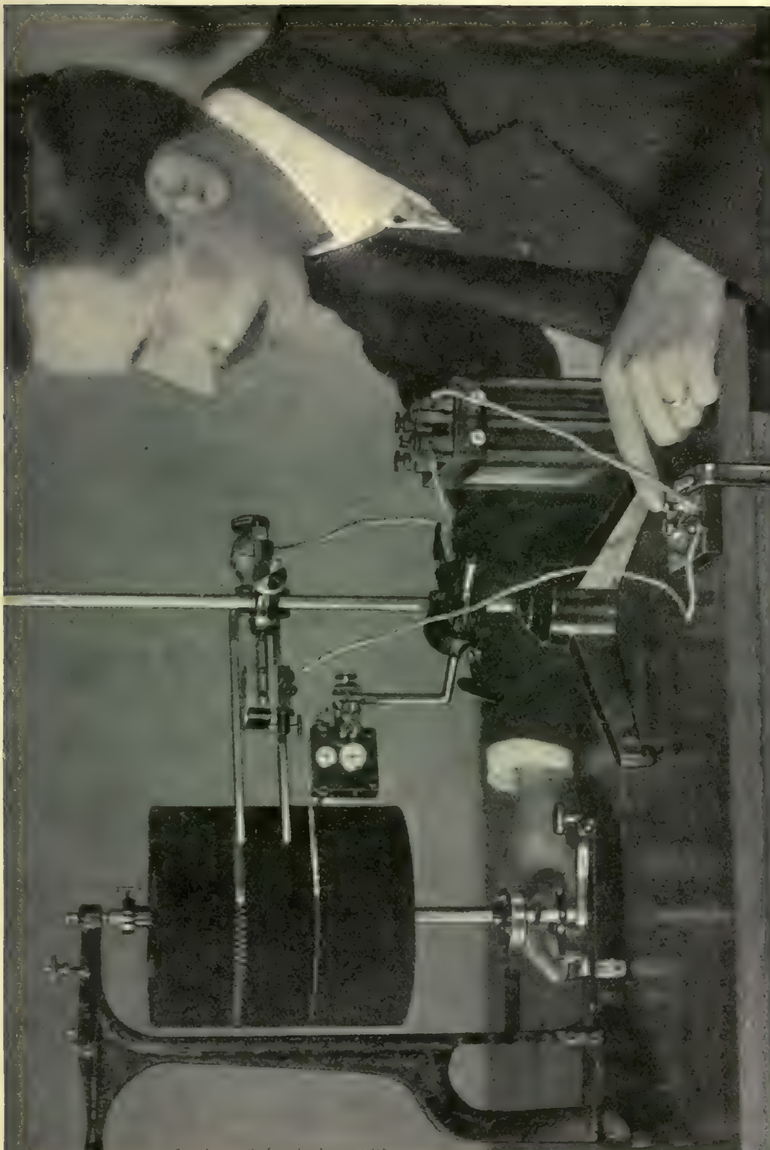


FIG. 149.—Testing a tuning-fork with the Jaquet chronometer.

such a tuning-fork with the electro-magnet between the two arms. The current flows from the battery to the screw at the right, through the fork itself, through the bent platinum wire to the screw at the left, from there through the electro-magnet to the screw in the middle. From here we connect with a recording-magnet, which writes down the oscillations on a kymograph. When the circuit is closed the two arms of the fork are bent inwards. This prevents the point from touching the screw and the circuit is broken, the arms swing outwards and so on, just on the principle of an electric bell.

The tuning-fork may be fastened on a stand (Fig. 149), and so mark its own oscillations by means of a writing-

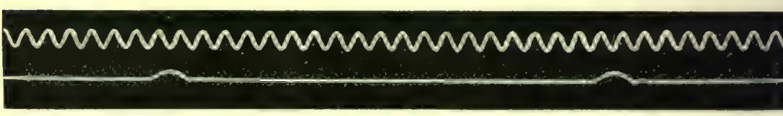


FIG. 150.—Tuning-fork oscillations and two marks of the Jaquet chronometer.

point. It is most convenient to use a tuning-fork with 100 oscillations per second. The tuning-fork itself may be tested by taking a curve of a Jaquet chronometer at the same time. Fig. 149 shows the arrangement of the apparatus and Fig. 150 the curves obtained from such a test. The chronometer was fixed for marking fifths of a second, and the curve shows that the tuning-fork recorded exactly twenty oscillations during this period. Similarly we can test the spring or the clapper of the electric bell with the metronome shown in Fig. 58.

But let us return to the transit of a star. We mark on the drum a vertical line from top to bottom and this stands for the star. (In Fig. 151 we cannot see this line, as it is at the other side of the drum.) The thread of the telescope is represented by the metal stand to the left of the apparatus. It would be better, of course, if we were

to stretch a white thread vertically in front of the kymograph. The moment the "star" passes the stand, the child must let go the tapping-key (Fig. 152). This breaks the

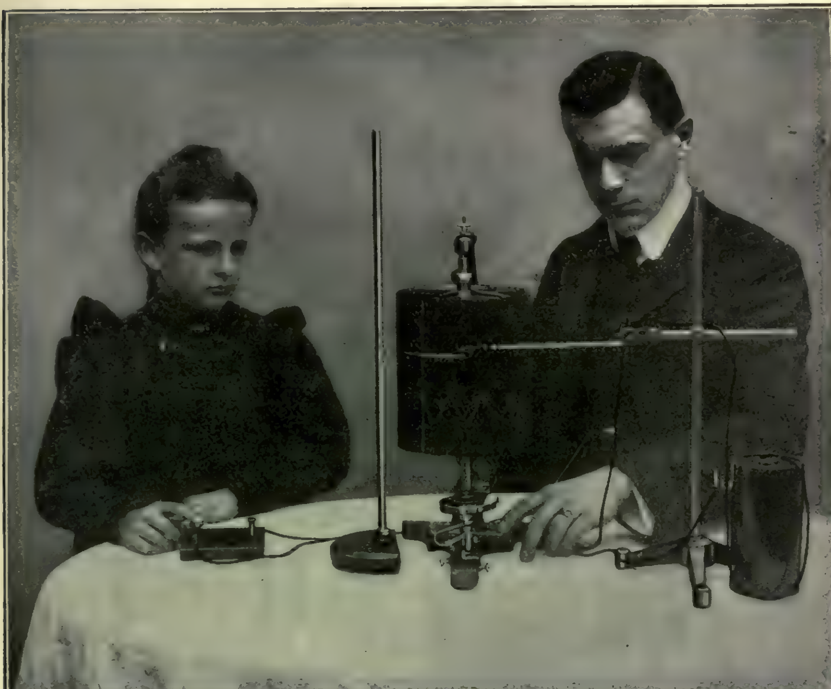


FIG. 151.—A simple reaction experiment. Graphic method. Optical stimulus.

circuit, which goes from a battery to the recording-magnet, then to the tapping-key, and then back to the battery.

Before starting the experiment we place the kymograph so that the "star," the white line, stands exactly behind the stand. We then draw another vertical line on the other side of the drum, exactly at the place where the writing-point of the recording-magnet

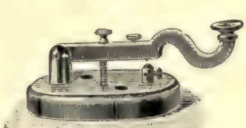


FIG. 152.—Contact key.

touches the drum. (This line can be seen in Fig. 151). Now the experiment can begin.

The child presses down the key and looks attentively at the stand. The experimenter stretches the spiral spring, and while releasing the catch says, "Ready." The drum turns, the writing-point of the recording-magnet is pulled downwards by the current and draws a horizontal line in this position. Now when the first vertical line passes the stand, the other vertical line must be exactly at the writing-point of the recorder. The child lets go the key "at once," and the writing-point jerks upward. We see however, from Fig. 151, that the letting-go of the key does not follow "at once," but about one oscillation of the recorder (in this case $\frac{1}{5}$ second) later. The child, in observing the transit of a star, has made a mistake of $\frac{1}{5}$ second.

If we test different observers according to this method, we find that each child has his peculiar way of observing, each one has his "personal equation." Among others we find a great number of individuals who let go the tapping-key before the "star" has gone past. They see the star, so to say, before it is really there. How can we explain this? If we consider this closely, we see that we have here a very complicated process to deal with. It concerns the co-ordination of two groups of muscles, the muscles of the finger and of the eyes. Some observers do not fixate the stand, but follow the approaching line with their eyes (or at least with their attention in indirect vision), and at the same time keep the muscles of their fingers in readiness, in order to achieve as nearly as possible a union of the two movements (the approach of the eyes to the stand and the lifting of the finger). According as they pay more attention to the one or to the other group of muscles, the finger is lifted before or after the objective meeting of stand and line.

A psychological analysis would only be possible in this case, if the conditions could be simplified.

II. REACTION EXPERIMENTS WITH THE GRAPHIC METHOD

1. Reaction to an Optical Stimulus

Psychologically considered our experiment will be much simpler, if I hide the left side of the child's field of vision by means of cardboard. Now it cannot follow the approaching line any longer, neither by means of eye-movement, nor with its attention in indirect vision. It can only fixate the stand, and when the line appears, carry out the finger-movement as quickly as possible.

What we are measuring in this experiment, a so-called reaction experiment, is an act of volition of the simplest kind. Each process of volition, looked at from the outside, can be limited by two moments—the appearance of a stimulus, and at the other end the movement of some muscle. So it is when a baby grasps at an apple. The appearance of the image of an apple is the stimulus, and with the grasping at the apple the process of volition is completed.

In our experiment the stimulus was an optical one. We can, however, with a very small change carry out the same experiment with an acoustical stimulus.

2. Reaction to an Acoustical Stimulus

Fig. 153 shows the arrangement of an experiment with an acoustical stimulus. This time only one vertical line is drawn on the drum, and the writing-point is so placed that it just touches the line when the steel-point at the

bottom of the kymograph is passing over and touching the piece of brass. In doing this the steel-point causes a

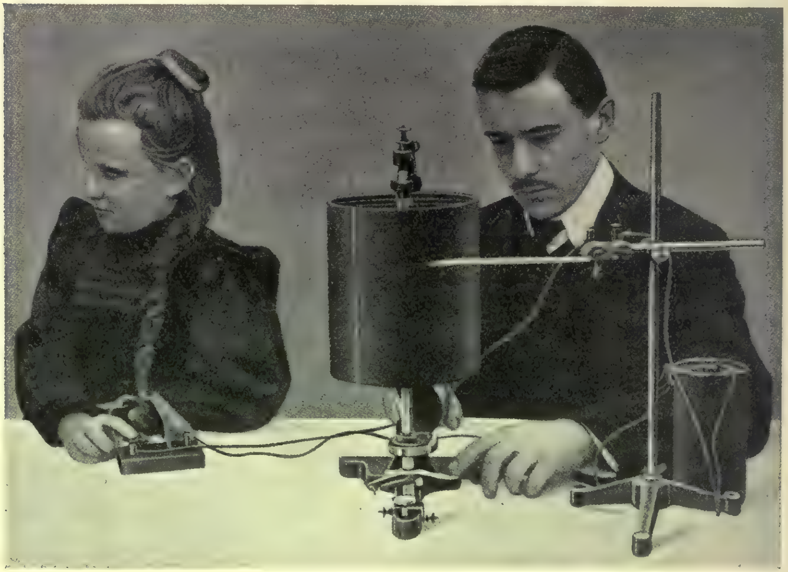


FIG. 153.—A simple reaction experiment. Graphic method. Acoustical stimulus.

sound. The observer has to react on this sound. He should be sitting with his back to the apparatus and his

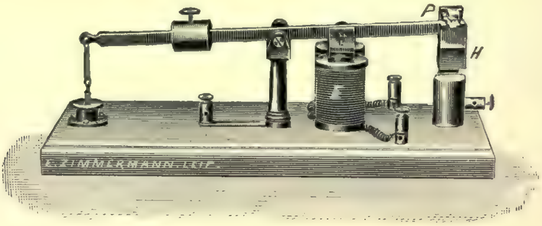


FIG. 154.—Electro-magnetic sound hammer.

eyes shut. The experiment proceeds exactly as the previous one we have described.

A louder sound must be used for demonstration before

a large audience. For this purpose the sound-hammer shown in Fig. 154 is used. If I send an electric current through the magnet (by connecting the two screws right of E with a battery), the hammer, H, is drawn down and strikes the anvil. If I arrange another circuit by means of the two screws, one at the right and the other at the left, then this will only be closed when the hammer touches the anvil. The following is our arrangement for the experiment (Fig. 155): —

First circuit: from the white battery standing on the table, to the recorder at the top of the stand. This recorder was made out of an electrical bell. (Time record.)

Second circuit: from the contact screw of the kymograph to the electro-magnet of the sound-hammer. (The dry battery stands left in the picture.) This circuit is closed the moment the steel pin touches the brass contact when the kymograph is in motion.

Third circuit: from the left battery in the front to the sound-hammer, through the hammer, anvil, second recorder, and back to the battery. This circuit is closed the moment the hammer touches the anvil. This moment is marked by the recorder.

Fourth circuit: from the right battery in the front to the tapping-key, to the third recorder and back to the battery. This recorder marks the moment when the child lets go the tapping-key.

For this experiment I used two kymographs, one with clockwork and one with the spring arrangement, and arranged them on the table as seen in the picture. I thus obtained a long slip of paper to take my records on.

In the experiment seen on the picture there are about eight oscillations between the striking of the hammer and the letting go of the tapping-key. Each oscillation measured 60 thousandths of a second. We generally

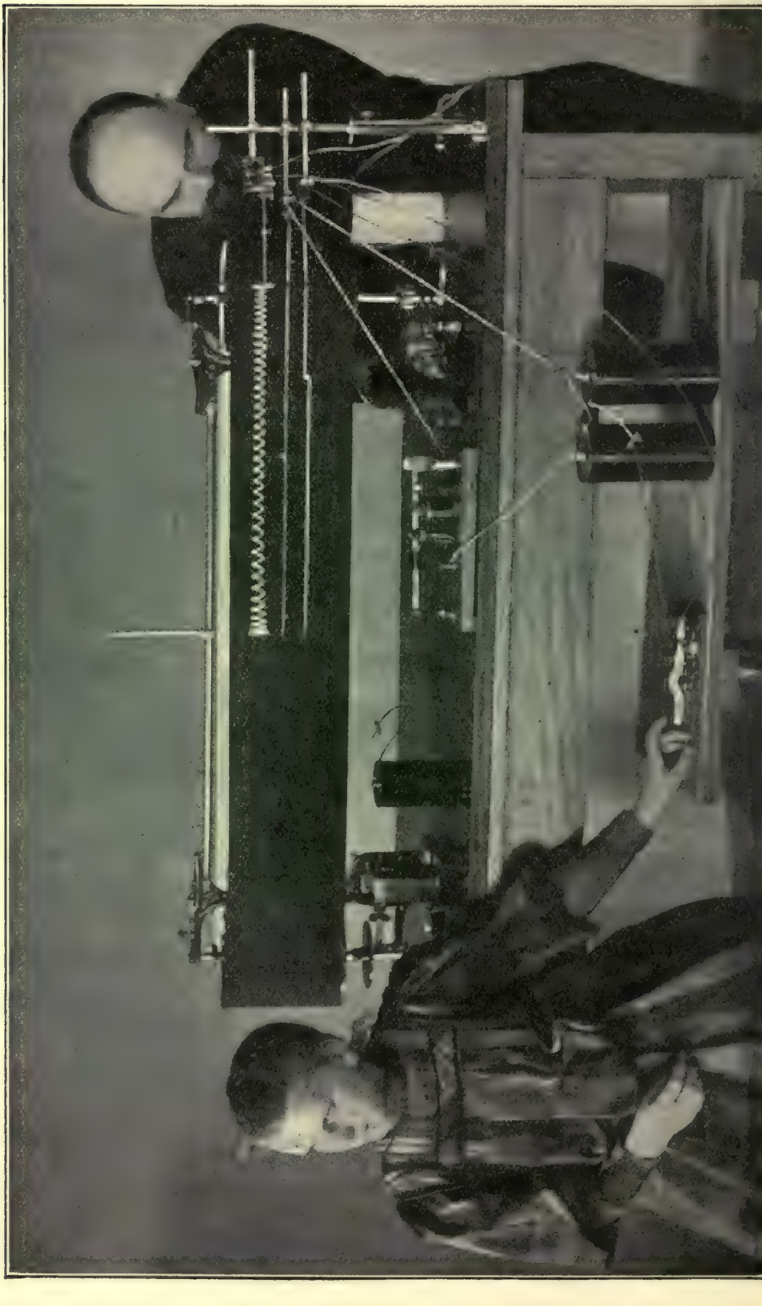


FIG. 155.—Acoustical reaction by means of the sound hammer.

write 60σ, σ (sigma) being equal to a thousandth of a second. The reaction, therefore, lasted 480σ or about $\frac{1}{2}$ second, a very long time for an acoustical reaction. The child was not yet practised in these experiments. The normal reaction time for sounds for adults is $100–120\sigma$, for optical stimuli $180–250\sigma$.

With our arrangement we could also employ a touch stimulus, by connecting an induction-coil with the brass contact of the kymograph, whereby the observer gets a slight electrical shock. The reaction times for touch stimuli are generally still shorter than for sounds. But these differences are of little interest to us, since they most of all depend upon physiological conditions. The stimulus works quicker in the "mechanical" senses (touch and sound), than in the "chemical" ones (sight, smell, and taste). The reaction times for smell and taste are generally very much longer than those for sight.

III. REACTION EXPERIMENTS WITH THE REGISTRATION METHOD

Instead of recording the time directly (the graphic method), we can also obtain time measurements by means of a special clock. From the position of the indicators we read off the length of the reaction process (the registration method).

Hipp's chronoscope (Fig. 156) is generally used. It is an electric clock, which is driven by means of a weight, and which can be set in motion or stopped by pulling two cords.

As soon as one of the cords is pulled the wheels are set in motion (see diagram on Fig. 250). At the same time the metal spring F oscillates up and down, and it is so tuned as to make 1000 oscillations per second. The quickest wheel of the clock S moves the distance

of one tooth further, every time the spring jumps upwards. This wheel therefore jumps precisely one tooth further every thousandth of a second. The little indicator of the upper clock-face is connected to this wheel. Each movement of this indicator denotes, therefore, a thousandth of a second. The indicator of the lower clock-face shows tenths of a second. If at the beginning of a reaction experiment the lower indicator pointed to 23 and the upper to 84, and at the end of the experiment the lower to 25 and the upper to 56, we have therefore moved from 2384 thousandths to 2556 thousandths. The reaction time will therefore be $2556 - 2384 = 172$ thousandths of a second or 172σ.

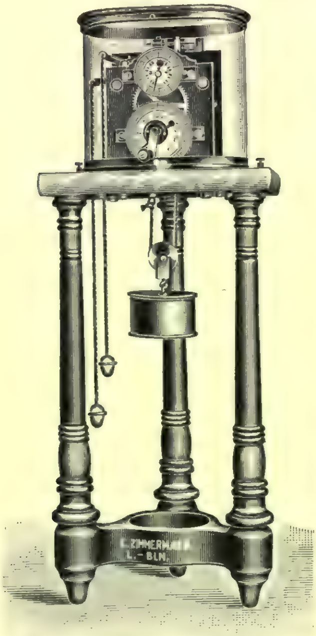


FIG. 156.—Hipp chronoscope.

Now the indicator Z_2 and therefore the indicator Z_1 do not revolve when the clockwork alone is set in motion, because the axle *xx* of the indicator Z_2 goes through all the wheels as an independent axle, and, along with the cross-bar *h*, fixed on D the axle, is held tight by the spring, which keeps the anchor *m* away from the magnet, and therefore, by means of the lever, presses *xx* to the left, so that the cross-bar *h* engages the teeth of the crown wheel K_2, which is stationary. Therefore the indicator is generally stationary even when the clockwork is in motion. If, however, I send an electric current through the electro-magnet F_2, the anchor *m* is pulled downwards, and thereby the screw *y* moves towards the

right. The spring *g* jerks the axle *xx*, the cross-bar *h*, and the indicator Z_2 towards the right, so that the cross-bar *h* engages the teeth of the crown wheel K_1 (as the first diagram on Fig. 250 shows). Now since the crown wheel K_1, which is in connection with the wheel S (by means of the wheel R_3), is in continuous motion, so the indicators are now set in motion by the clockwork. As

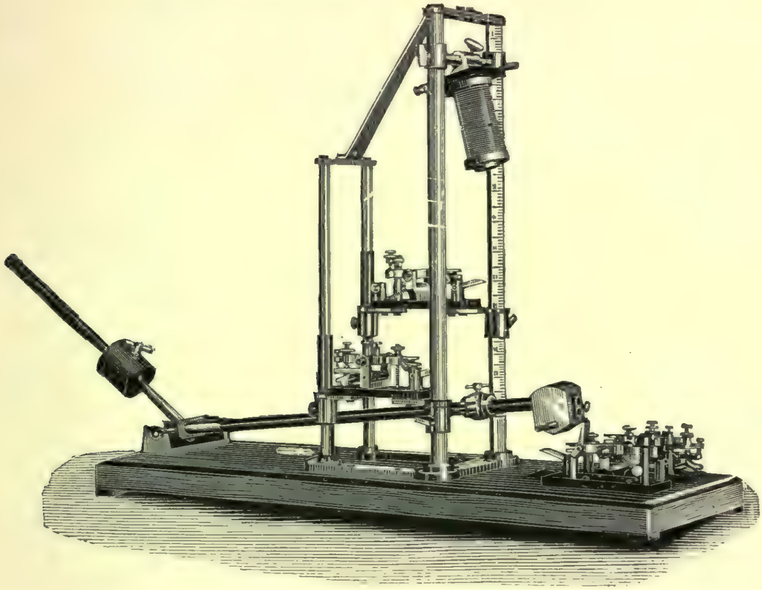


FIG. 157.—Wundt's control hammer.

soon as I shut off the current, the anchor *m* is pulled upwards by the spring F and the axle *xx* with the cross-bar *h*, and the indicator Z_2 is again pressed towards the left, and the indicator stops even although the clockwork continues. The indicator only moves with the clockwork as long as a current goes through the electromagnet.

For a reaction experiment we must so arrange it that the stimulus (say the striking of the sound-hammer)

closes the circuit, and the reaction (say the letting go of the key) breaks the circuit again.

There is however the following difficulty. The measurement can only be accurate, if the pulling of the anchor on to the electro-magnet follows as quickly as the pulling of it away by the spring. Both forces must therefore be accurately balanced against each other. The chronoscope must therefore be accurately tested, by means of Wundt's control hammer (Fig. 157) or Ebbing-

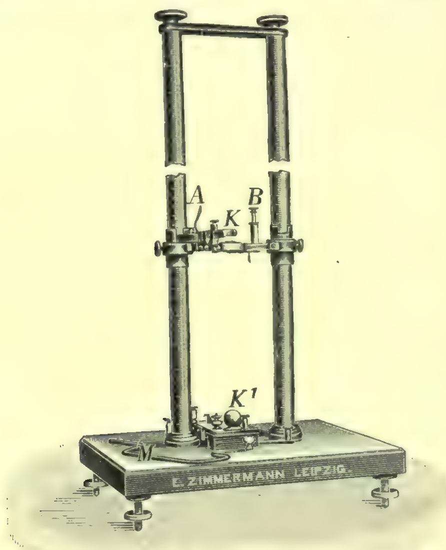


FIG. 158.—Ebbinghaus' gravity apparatus.

haus' gravity apparatus (Fig. 158). Besides this the strength of the current must be measured during the experiments and kept constant by means of a resistance.

The arrangements we must make for experiments with such apparatus become, as can be imagined, fairly complicated, and therefore they cannot be recommended for pedagogical experiments. For this reason I have described the graphic method in much greater detail, although it is unfortunately seldom made use of in reac-

tion experiments. The only inconvenience is the reckoning out of the curves. The advantages of the method are great simplicity and accuracy.

The registration method could only be recommended if we could simplify the chronoscope.[1]

IV. THE METHOD OF INSERTION

What we have measured in our reaction experiments is the time of a simple volitional process. In this time are included, according to Wundt, the following seven partial processes :—

1. The stimulation of the organs of sense. 2. Transmission to the central nervous system.	Physiological processes.
3. Entrance of stimulus into the field of consciousness. 4. Entrance of stimulus into the fixation-point of consciousness. 5. The start of the volitional process.	Psychological processes.
6. Transmission from the central nervous system to the muscle. 7. The stimulation of the muscle.	Physiological processes.

It can scarcely be hoped that we shall ever be able to measure these different processes separately, and so arrive at pure psychological times.

This may however be possible by another method. After I have determined by many experiments the simple reaction time of a child, I may complicate the process, I can insert a recognition or choice of stimuli, &c. We shall of course obtain longer reaction times. If we subtract from these figures the simple reaction time, we shall get times which may be called "recognition times," "choice times," &c.

Discriminative reactions can be very easily carried out

[1] See Appendix I.

with our arrangement. There are two contacts with springs on our kymograph. We can therefore choose two springs which give different tones, and we can tell the observer only to react to a certain one of them. In our experiments we change about from one tone to the other irregularly.

Similarly we can carry out selective reactions, by demanding the observer to react with the right hand on the high tone, and with the left on the deep tone. Of course there must be two keys and two recorders. Lastly, several stimuli may be used, say one for each finger, and

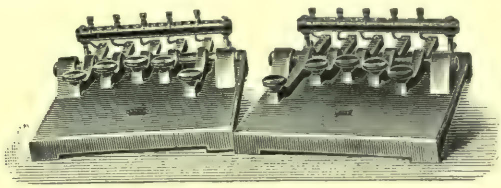


FIG. 159.—Five-finger reaction keys.

for this purpose two five-finger reaction keys are used (Fig. 159).

This method has been called the " insertion " method, because we insert more complicated processes.

We have now learnt the three most important psychological methods :—

1. The pure impression method (for sensation and perception).
2. The expression method (for feelings).
3. The insertion method (for volitional processes).

V. MUSCULAR, SENSORIAL, AND NATURAL REACTION

Let us return once again to the simple volitional process, say to the acoustical reaction represented on Fig. 153. Even in this simplest case the " personal equation " remains, *i.e.* there are individuals whose

volitional processes take on an average a longer time than those of other individuals. For example, the reaction time to an optical stimulus may be for one individual 180σ, and for another 250σ. An accurate psychological investigation shows that essential differences in the process of volition go hand in hand with these differences in time. The one observer turns his attention almost exclusively to the stimulus (sensorial or complete reaction), the other almost exclusively to the movement to be carried out (muscular or shortened reaction). Besides these we have the so-called natural or central reaction, where the observer divides his attention as equally as possible between

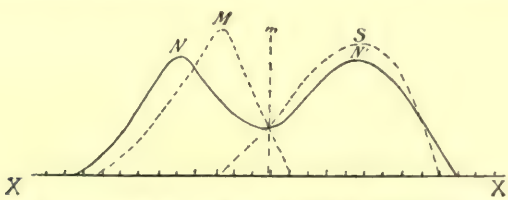


FIG. 160.—Diagram of frequency curves in reaction experiments, according to Wundt.

(From Wundt, *Outlines of Psychology*, p. 225. Engelmann.)

the stimulus and the movement. A perfectly equal division of attention is however never possible. In every single experiment either the stimulus or the movement receives an essentially larger share of the attention. If I therefore carry out 500–1000 experiments and arrange them according to their length of time on a frequency curve, I will not get a simple curve with one summit, but such an one as is shown in Fig. 160. The two summits show that sometimes more attention was directed to the stimulus (this might give as central value 250σ), and sometimes more to the movement (central value 180σ). The dotted line shows the distribution of muscular and sensorial reactions.

Fig. 161 shows the distribution obtained for all three

forms of reaction out of a great many experiments. The maximum for the shortened or muscular reaction lies at 150σ, for the natural reaction at 200σ, for the complete or sensorial reaction at 220–240σ. The natural reaction does not show in this case two summits as we should expect. There are, of course, exceptions to this.

Wundt maintains that the natural reaction shows the original form of the process of volition.

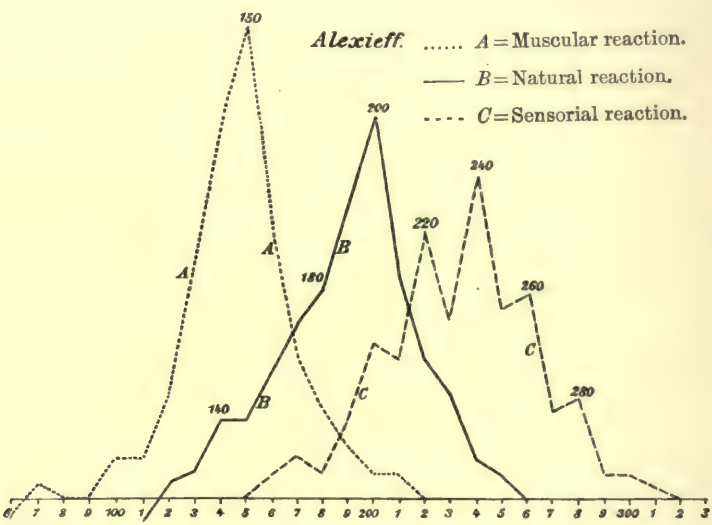


FIG. 161.—Distribution curves of muscular, natural, and sensorial reactions.

(From Alexieff. *Philosophische Studien*, 16. Engelmann.)

It would therefore be of the greatest importance to study the process of reaction of children according to the method of frequency curves. Here we should get the natural reaction in its purest form.

VI. PEDAGOGICAL INFLUENCE ON THE PROCESS OF VOLITION

If the natural form of reaction is the original one, we must take for granted that special conditions cause the

appearance of the other forms of reaction, the muscular and sensorial. The idea at once arises that we should then

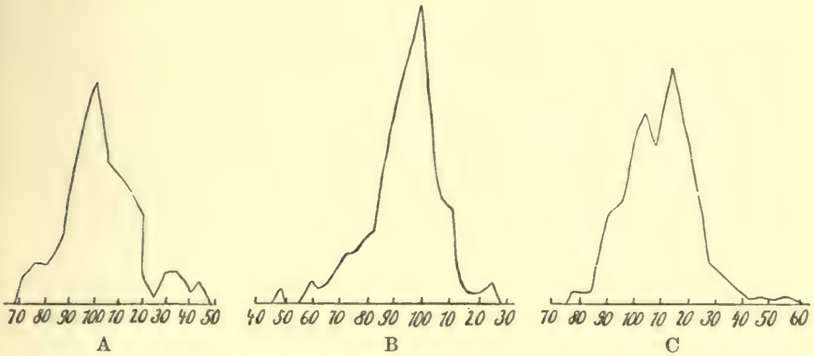


FIG. 162.—Distribution curves of the reactions of an observer with decided muscular reaction tendencies. A, natural reaction (205 tests); B, practice in muscular reaction (291 tests); C, in sensorial reaction (590 tests).

(From Wundt, *Physiol. Psychologie*, Bd. III. Engelmann.)

be able to produce these forms artificially. Such experiments have been carried out by Wundt's pupils.

Fig. 162A gives the natural reaction form of an ob-

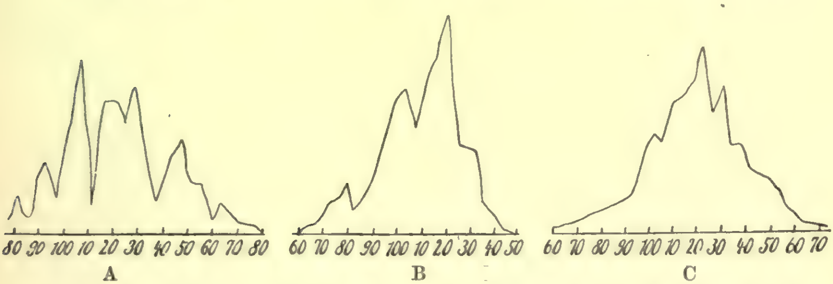


FIG. 163.—Distribution curves of the reactions of an observer with decided sensorial reaction tendencies. A, natural reaction (150 tests); B, practice in muscular reaction (374 tests); C, in sensorial reaction (1138 tests).

(From Wundt, as in Fig. 162.)

server, who, as we can see, already reacts fairly muscular, yet we see also that a number of sensorial reactions are included, since at 130σ a second smaller summit appears which stretches to 150σ. The observer was then told to

pay special attention to the movement. We see the result in curve B. The reaction is now much quicker. Reactions over 130σ have entirely disappeared, and some have sunk down to less than 50σ. With special attention paid to the stimulus, we get curve C. Here we find values up to 160σ. Values under 70σ have disappeared. This is sensorial reaction.

Fig. 163 shows us how an observer who naturally reacts very sensorially, can by practice produce the purely muscular or sensorial forms.

Fig. 164 shows the single steps in the reverse process

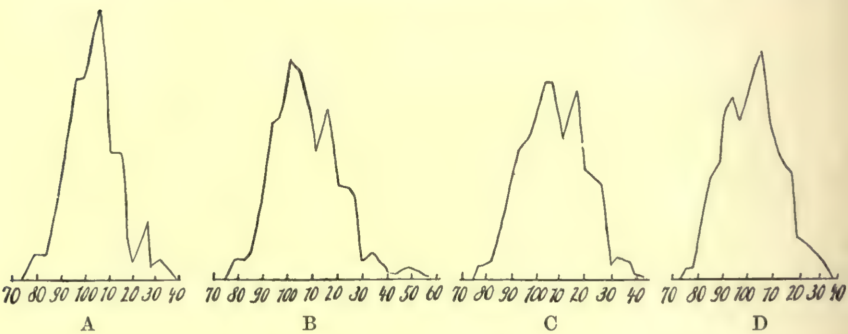


FIG. 164.—Progress of practice in changing from decided muscular to sensorial reaction. 590 tests in 10 groups.

(From Wundt, as in Fig. 162.)

of practice. A is essentially muscular reaction. By trying to observe the rule to pay special attention to the stimulus a second summit appears, at first small in B, and then larger in C. And at last the second summit becomes the main summit in D.

It is noteworthy that the distribution or mean variation plays an important part in such experiments. In general the distribution becomes smaller with practice; the distribution of curves of muscular time is the smallest.

These experiments show that the simple process of

volition can be changed by systematic influence, so that it takes either a muscular or sensorial form.

Muscular reaction must therefore be looked upon as a shortened form of the process of volition—the process becomes more mechanical. Certain parts of the process, *e.g.* the entrance of the sensation into the fixation-point of consciousness, must either fall out or follow after the movement has been carried out. This is the reason why mistaken reactions often occur. The observer sometimes reacts to quite a different stimulus, say a slight tremor of the table, &c. Early reactions also appear. The observer reacts even before the stimulus appears. The signal joined to a sense-perception of a period of time that has passed (which to the observer seems equal to the usual time between signal and stimulus) is often sufficient to make the movement take place.

Since fewer factors are present in the muscular reaction than in the other forms (certain psychological processes have dropped out), the distribution or mean variation is smaller. The times are all fairly equal and only differ slightly from one another.

The sensorial process on the other hand shows the complete volitional process, in which the psychological part is quite complete, with perception (entrance of the sensation into the field of consciousness) and apperception (entrance into the fixation-point).

Because of the greater number of processes, the sensorial reaction shows a correspondingly greater distribution.

It is worthy of note that, in the experiments in which different reaction forms were practised, the sensorial, *i.e.* the complete, reaction was found more difficult of attainment than the muscular. In cases where the observer had previously accustomed himself to muscular reaction, it was found almost impossible to return to sensorial

reaction. A complete volitional process could not be achieved. The observer helped himself along with certain rudiments of the same. If our definition of pedagogy is agreed to, namely that it has to deal with the investigation of the methods which can be employed to influence systematically the development of a human being (*cf.* p. 7), then it must be admitted that these experiments of Wundt's pupils, that have just been described, fulfil all the conditions of a pedagogical experiment.

This is a classical example of the essence of a pedagogical experiment. It shows how we try to arrive at the simplest processes (simple reaction) by accurate analysis, and then going out from the natural progress of this process (natural reaction), first of all its natural development is investigated (the change in reaction form during a number of experiments without special conditions). Then special conditions are introduced (attention to the stimulus or to the movement), and the changes in development are established (transition to the muscular and sensorial forms). Here we obtain at the same time criteria to judge the value of the means of education employed. For instance, training in muscular reaction makes a return to sensorial reaction impossible; the opposite way, however—first training in sensorial and then in muscular—is possible.

An important pedagogical question is still left open after these experiments. It still remains to be investigated, whether an observer, who has for a long time been practised in sensorial reaction, and who afterwards makes the volitional process mechanical (muscular reaction), whether such an observer will make fewer mistaken and early reactions than another observer, who is at once trained in the muscular form without being trained in the sensorial form.

Here arise at once practical pedagogical questions. Without doubt certain processes of volition must be shortened or made mechanical in order to disencumber the central nervous system. It must be left free for other higher functions. Think of technique and soul in piano-playing. The important question is, at what stage of development should such processes be made mechanical? If this is done too early we shall get a phenomenon like muscular reaction in its extreme form with its early and mistaken reactions.

In investigating the volitional processes of school-children the following questions in accordance with what we have said remain to be answered :—

1. What form of reaction do children show? Is it the natural form with two summits on the frequency curve? [1]
2. How does the form of reaction of children (especially of individual children) change as they grow older?
3. What natural changes do children show in carrying out many acts of will without special conditions?
4. Which form of reaction (sensorial or muscular) can be more easily achieved with children?
5. What differences appear in regard to mistaken reactions, if the child is immediately trained for muscular reaction, or if a period of training in sensorial precedes this?
6. What influence has age and special training on the distribution of the errors?

And lastly another point. By what means have the psychologists tried and achieved a change in the volitional

[1] In reaction experiments carried out by the translator with twenty children (ages 7–14), the great majority of the curves for natural reaction showed two or more summits.—*Translator's Note.*

process? By no other means than by repeatedly carrying out processes of will (under certain conditions). Pedagogy should take this to heart. All educationists are by no means clear about the following important law: If we can achieve by pedagogical means a schooling, a strengthening, a moulding of the volitional processes, we can only do so by giving the child, in a systematic manner, an opportunity to carry out repeatedly acts of will.

FIG. 165.—The training of the will by games.

(From Schnell, *Übungen im Schulturnen.* Voigtländer.)

The will cannot be steeled by speechifying, by good counsel or by regulations, but only by actions.

We are involuntarily reminded of Kleist's epigram, "When you admonish the children, you think you are doing your duty as a teacher. Do you know what you are teaching them? To admonish."

Fig. 165 seems to have little to do with these psychological questions. The boy is keeping all his muscles ready to carry out a certain movement that is necessary in the game he is playing. He has done this, perhaps, a hundred times. He is obtaining a control over his muscles, training his will to act as he wants it to. He is gaining more to strengthen his will than all the most beautiful speeches or admonitions would give him.

The ethical side of the training of the will I have not discussed. Only the formal training belongs to this chapter.

CHAPTER VI

CONSCIOUSNESS AND ATTENTION

I. THE MIMICRY OF ATTENTION

1. The Photographic Method

If we try to exert any pedagogical influence we must begin by setting up our "task." We must, of course, extend our idea of "task" pretty widely. For example; the teacher comes into the class-room with a packet of nuts without saying a word. The youngsters become inquisitive—"What's in it?" "Oh, what a heap of nuts!" and so on. Now this bringing the nuts into the room can be a task, in as far as this procedure was chosen in following out a certain end for the development of the child. The setting of a task consists, at least, in calling forth a complex idea, which is always made up of a great number of elements. We demand from the pupil that he should grasp these elements simultaneously, and that he should separate them from the crowd of other ideas and impressions that are pressing upon him (internal bodily sensations, small noises, the noise in the street, &c. &c.). Only thereby can he attain to the "clearness" which is necessary for further pedagogical use. We call this process of bringing to the front certain elements of our consciousness, so that they may become clearer, the process of attention.

It is therefore of the greatest importance to pedagogy to obtain an accurate description of attention; further

to measure how many separate elements the attention can simultaneously bring into clearness (the scope of attention); and lastly, how many elements altogether (clear and unclear) consciousness can grasp at one moment (scope of consciousness).

FIG. 166.—Optical attention. Head and hands raised.

How great the importance of the process of attention is in the development of the child can be seen from its physical concomitants, which in young children engage the muscles of almost the whole body. Besides the outwardly visible symptoms there are changes in the breathing and circulation. (We have already described the

methods of investigating these.) No one can be in doubt about the fact, that the children in Figs. 166 to 168 are in a state of attention. In Fig. 167 we see how the attention first of all shows itself in the adjustment of the sense organ in question. The finer changes, the accommodation of the lens of the eye to the distance, the adaptation of the eye to the brightness

FIG. 167.—Eighteen-months-old child looking at a flying swallow. Optical attention.

FIG. 168.—The same child, a few moments later. The optical attention is much more intense.

(From Sante de Sanctis, *Die Mimik des Denkens.* Marhold.)

of the object, all these, of course, cannot be seen in the photograph. In Fig. 168 the attention increases, and we see how the motor excitement takes possession of the whole body in such a manner that all the muscles (here especially those on the left side from where the stimulus comes) have the tendency to turn the body, and especially the sense organ, towards the stimulus.

N

The difference between acoustical and optical attention is obvious by comparing Figs. 169 and 170.

FIG. 169.—Blind children listening. Acoustical attention.

Defective children (Figs. 171 and 172) show an abnormal (exaggerated) expression of attention or an absolute want of any symptoms of expression.

At a later age the mimicry of attention is gene-

FIG. 170.—A deaf and dumb boy reading from the lips of his teacher. Optical attention.

rally limited to changes in the muscles of the forehead.

During the first years of school, however, the expression of attention is generally fairly well marked[1] (Figs. 173 and 174), and it would therefore be a very thankful task to investigate by means of the photographic method these physical symptoms of expression in school-children of every age.

In the upper classes an investigation of the muscles of the forehead is to be preferred. Here the method described by Professor Sante de Sanctis is to be recommended:[2]

FIGS. 171 and 172.—Defective children. Left, in a state of indifference. Right, optical attention; here the mimicry seems to denote pain, as if the boy wished to protect his eyes against some too powerful light.

(From Sante de Sanctis, as in Fig. 167.)

"The forehead is made damp with a watery solution of hyposulphate of soda and alum, such as is used for an ordinary photographic fixing-bath. Copying paper is laid for a few seconds on the wet forehead, and then exposed to light. It will then contain a photograph of the forehead. An ordinary fixing-bath makes the photo-

[1] In the eight-year-old children (Fig. 173) the mimicry of attention, which is most of all concentrated in the muscles of the forehead, spreads out to the most outlying groups of muscles even when the thinking is simple. When the task is more difficult, as in arithmetic, it is as if a whirlwind rushed over the small faces and shook every branch and twig (Fig. 174).

[2] Sante de Sanctis; *Mimik des Denkens.* Marhold, Halle, 1906.

FIG. 173.—The mimicry of attention of eight-year-old children when thinking of something easy.

("Think which was the way we took on our last walk.")

Fig. 174.—The strongly marked mimicry of eight-year-old children in a state of concentrated attention.

(A difficult problem in mental arithmetic.)

graph permanent." In laying on the paper the child must, of course, be in the state of attention we wish to investigate. Fig. 175 shows a photograph of the muscles of the forehead obtained by this method.

A similar method was invented by Professor Sommer. He takes a piece of smoked paper and presses it quickly

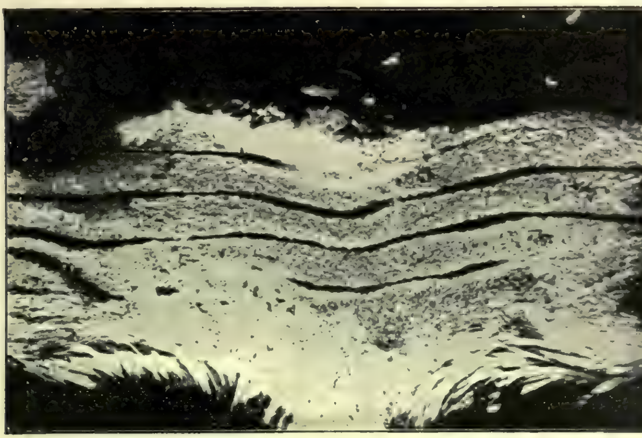


FIG. 175.—Contraction of the *musculus frontalis* on command. Two perfect and one imperfect horizontal line. Photographic copy.

(From Sante de Sanctis, *Die Mimik des Denkens*. Marhold.)

against the forehead. This is fixed by dipping it into a solution of shellac.

2. The Graphic Method

The photographic method only registers one moment of the state of attention. If we wish to study the whole progress of the state, we must turn to other methods. A cinematographic exposure, because of the cost and for other reasons, is not to be recommended. Better is the method proposed by Professor Sommer. We shall give a description of this method.

(a) *Movements in Two Dimensions.*

We choose a special part on the forehead where the mimicry of attention is most marked. The whole apparatus (Figs. 176 and 177) is then fastened on the head by means of the bandage B and the small suction-cap G, on the special part to be investigated. The suction-cap participates in all the movements of that part of the

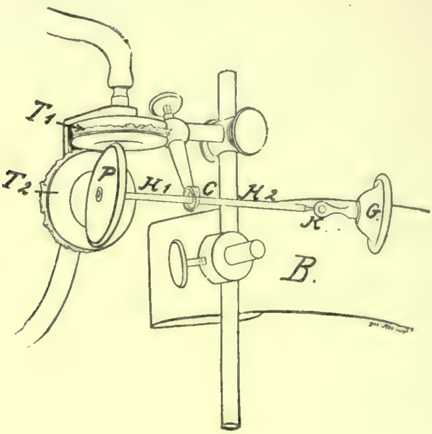


FIG. 176.—Sommer's apparatus for analysing movements in two dimensions. (Muscles of the forehead.)

forehead. It transmits the movements to the plate P. This plate presses against two flat tin capsules, T_1 and T_2, which have a thin rubber covering like the Marey tambours (see p. 127). If the plate P moves upwards, it presses against the capsule T_1 and causes the air to rush along the rubber tube to an ordinary Marey tambour on a stand, as in Fig. 177. The writing-point, as usual, records these movements. These are the records of vertical movements of the forehead. The horizontal movements are recorded in exactly the same manner

by means of the capsule T_2 and a second Marey tambour. Both recorders write on a kymograph, and thus the

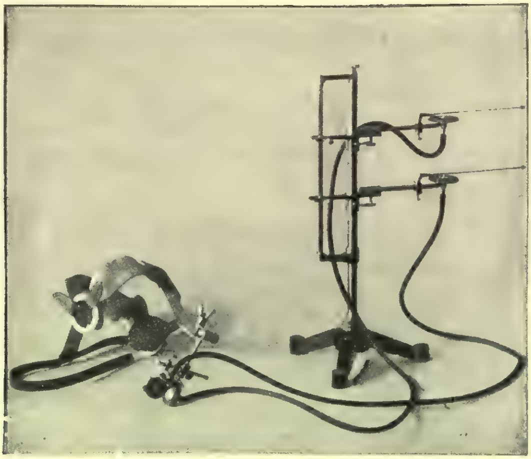


FIG. 177.—Sommer's apparatus for analysing the movements of the muscles of the forehead.

horizontal and vertical movements of the part of the forehead in question during the whole progress of the attentive process are recorded.

(b) *Movements in Three Dimensions.*

With the movements of the forehead a record of two dimensions is sufficient, since the changes in the third dimension, backwards and forwards, are very slight and may be neglected.

If, however, we wish to investigate the small movements that take place say in the muscles of the finger during a state of attention, we must record all three dimensions. Professor Sommer has also arranged an apparatus for this purpose (Figs. 178 and 179). The finger is placed in the apparatus in such a manner that it is in connection with three recorders, one for the movements

sideways left or right, another for the upward and downward movements, and a third for forward or back-

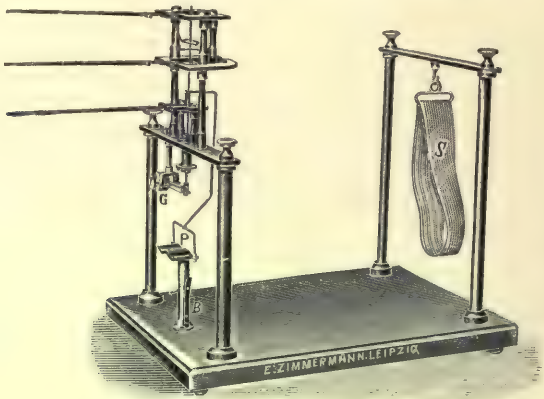


FIG. 178.—Sommer's tridimensional analyser.

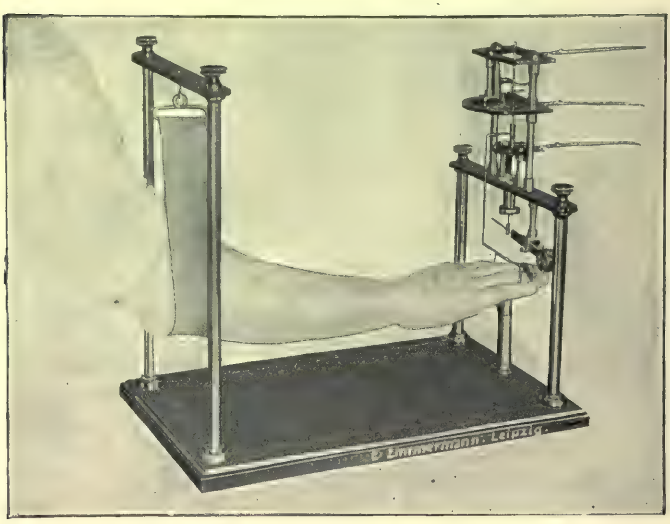


FIG. 179.—Sommer's tridimensional analyser.

ward movements. An investigation according to this method with children of about six years would certainly show very marked movements in all directions. The

technicalities of the experiment would be fairly complicated.[1]

The curve in Fig. 180 shows the sensitivity of this

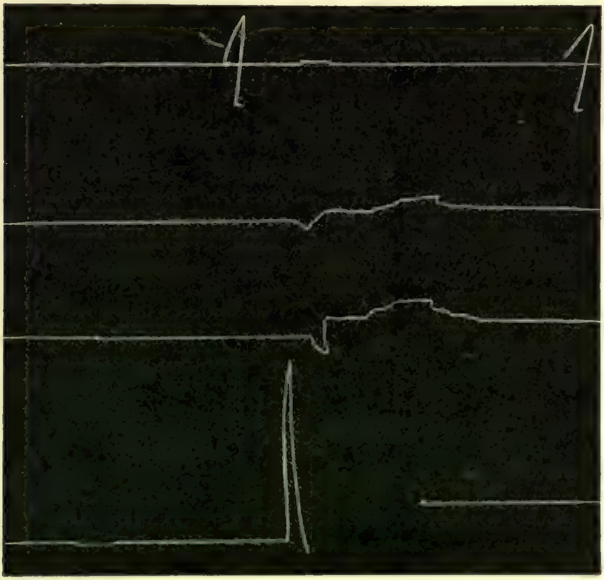


FIG. 180.—Curve of Sommer's tridimensional analyser. 1st curve—Time signal. 2nd curve—Pushing movements of finger. 3rd curve – Side movements. 4th curve—Downward movements.

(From Sommer, *Zeitschrift für Psychologie*, XVI. Barth.)

method. It was constructed in the following manner. A number of figures (1, 6, &c.) were placed before the

[1] It can never be the business of education artificially to restrain the strong expression movements of attention that are present in children. As long as these expression movements are so strong and vary so individually that it seems impossible to get the children to work together at some common task in school, then they ought not to be in school. During the period of transition to the quieter forms of expression, it is the business of education to suit the method of teaching to the kinds of attention that prevail, and not try to limit the expression symptoms. Rather the opposite. By cultivating the mimic powers a help is often afforded the attention, especially in cases of excessive dulness, *e.g.* with defective children. Sante de Sanctis describes such a case where he achieved good results.

observer, so that he might note one of them. He noted the "1." Now in irregular order different figures were laid before him. As soon as the "1" appeared, the observer involuntarily moved his finger. The top curve marks the time when the "1" was shown—the small rise in the middle of the curve. The other three curves show great changes at this moment. The second curve shows obvious movements of the finger forwards and backwards, the third side movements towards the right and left, and the fourth very marked movements up and down, so strong that for a moment the writing-point jumped away from the kymograph.

II. THE SCOPE OF ATTENTION

1. For Spatial Perception

We may take as a measure for the attention the number of elements that can be simultaneously brought into perfect clearness. When a complicated compound object is presented (say a landscape), our attention generally hurries quickly from one element to another (successive attention); we must therefore discover a method which prevents such a successive apprehension. We achieve this by showing an object (say a picture) for a very short time (about $\frac{1}{100}$ second).

The apparatus used for this purpose is called the tachistoscope. It consists of a screen covering the object, with a slit in the upper part. When this screen falls, the object can be seen for a short time through the slit (Fig. 181). Before the screen falls, it is so placed that a white point, the fixation point, stands exactly in the middle of the object that is hidden by the screen.

Simple spatial forms, such as lines, triangles, squares, &c., should be chosen (Fig. 182).

Such experiments have shown that adults can apprehend only up to six separate elements so distinctly that they can draw or accurately describe them afterwards.

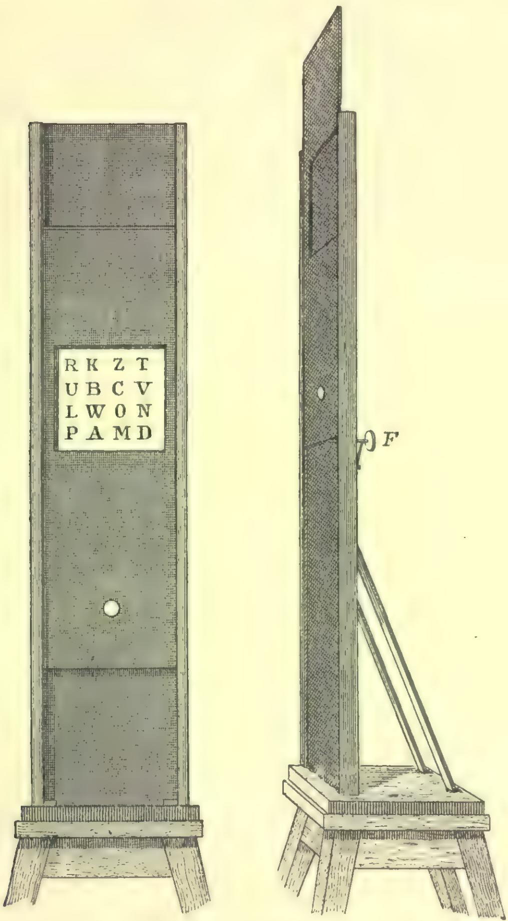


FIG. 181.—Demonstration tachistoscope, according to Wundt.

The attention, therefore, can encompass only six elements simultaneously.

Letters, which are in fact fairly complicated images, are treated as elements by adults, so that the number of

letters which can be apprehended at once also amounts to six. But here we do not accurately apprehend the many separate lines which go to make up the six letters (perhaps twenty or more lines), it is rather a process of assimilation, of which we shall have more to say later.[1]

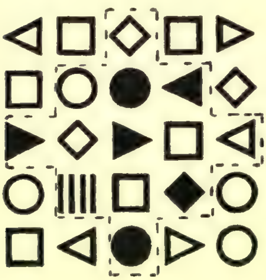


FIG. 182.—Optical stimuli for determining the scope of consciousness.

(From Wundt, *Physiol. Psychologie.* Engelmann.)

In testing the scope of attention of children we must pay special attention to two things—firstly, to the number of elements (lines) that can be simultaneously apprehended (the real scope of attention), and secondly, to the degree in which the scope of attention changes when we employ the "higher" unities, say letters, words, and sentences. The degree in which the adult is superior to the child in regard to these higher unities shows a great superiority in the unifying power of his apperception. This is of great importance for the economy of thinking.

2. For Temporal Perception

If simple elements of consciousness, such as rhythmical beats, *e.g.* the beats of a metronome, follow each other quickly enough, the attention is able to apprehend these successive elements at one grasp, if there are not too many of them.

If I let a metronome beat four times and then, after a short pause, five times, I notice at once that the second row possesses more elements than the first. Here also

[1] If senseless syllables are made up out of letters, we can read about ten letters in the tachistoscope. If a sentence is shown very often, 4–5 words, *i.e.* about 20–30 letters, can be apprehended at one glance.

our judgment up to six elements of consciousness is generally correct.

In these experiments two conditions are absolutely necessary. Firstly, none of the beats must be emphasised either subjectively or objectively. If so, a compound idea made up of different elements arises instead of a succession of elements of consciousness, and the attention deals differently with this than with separate elements. Secondly, the number of beats must, of course, never be counted. Both these conditions cannot be complied with by all adults. Even to suppress the tendency to count is not so simple. Many cannot prevent themselves from emphasising subjectively certain beats ($\frac{2}{4}$ or $\frac{4}{4}$ time, &c.). The tendency is so strong that even with a perfectly regular metronome we generally imagine that one beat is stronger than the other.

Because of these difficulties, such experiments cannot be carried out with children. To fix the scope of attention with them, we must therefore use the tachistoscope. Only such a tachistoscope should be used, where it is possible to determine accurately the length of time the object remains in view.

III. THE SCOPE OF CONSCIOUSNESS

1. For Spatial Perception

If a very complicated object (Fig. 182) is exposed in the tachistoscope, at first only a small number of the elements are apprehended, owing to the fact that the scope of attention is limited. We can, however, repeat the experiment with the same object, until gradually all parts are recognised and apprehended. Then, without previous knowledge of the observer, one of the elements is changed (say a circle is substituted for a square) and

the object is shown again. It often happens in such a case that the observer notices that something is different, but he cannot tell what. This only happens, however, if we do not exceed a certain number of elements (in our example the thirteen which are included within the dotted line). With a much greater number of elements, a change of one single element would not be observed. We therefore arrive in this manner at a certain limiting number, at a scope of our apprehension. But this time it is not the scope of attention we have measured, but the scope of consciousness. For we are not dealing with clearly apprehended (apperceived), but with less clearly recognised (perceived) elements. We could only tell that something or other had been changed.[1]

Determinations of the scope of consciousness of children would be of great importance, if they were carried out along with determinations of the scope of attention. We would then get a definite proportion between the scope of attention and the scope of consciousness. In the experiments described it was $\frac{6}{13}$ for adults. The size of this fraction would tell us more than the absolute figures 6 and 13. It would show us whether children are more inclined to apprehend a large number of impressions unclearly and only a small number of these clearly, than to apprehend only a few impressions, but a comparatively large number of these with great clearness.

Pedagogical attempts to educate the attention could be best tested as to their results by means of this method (comparisons between the scope of attention and of consciousness).

We can also investigate how the child succeeds in directing his attention. He is told first of all to spread

[1] The experiments described were carried out by Professor Wirth in Wundt's institute. Professor Wirth invented for this purpose a very ingenious apparatus—the mirror tachistoscope. See Wirth, Wilhelm., *Die experimentelle Analyse der Bewusstseinsphänomene.* Vieweg & Sohn, 1908

his attention over the whole field of vision (fluctuating attention). Then a few elements can be changed. In the next experiment we tell him to pay attention to the upper right-hand corner (fixed attention). Some elements are again changed, not at this corner, but somewhere else.[1] We have now to determine whether the changes are better noticed by fluctuating or by fixed attention, whether the scope of consciousness is greater in the one case than in the other.

A similar pedagogical problem presents itself, if we ask the question (say in treating an object of natural history), whether it is better to direct the attention of the child with equal intensity to all parts of the object, or to treat the object from different points of view (the cat as a beast of prey, &c.).

2. For Temporal Perception

To determine here the scope of consciousness a metronome is used, and every second, third, or fourth beat is emphasised by the striking of a bell. We thus obtain a complex temporal perception.

These experiments need not be described here because of the difficulties of conducting such experiments with children, as we have mentioned above (p. 207).

[1] In such experiments the line of vision is always the same. The fixation-point remains as before in the middle, and the axis of vision falls on this point. Only the attention is directed to a different point.

CHAPTER VII

ASSIMILATION

I. ASSIMILATION CAUSED BY SINGLE IDEAS AND GROUPS OF IDEAS

1. The Nature and Significance of Assimilation

The picture of the children in Fig. 183 is excellently carried out. We see clearly how the little girl, the second from the left, is turning round and looking at the child that she is leading by the hand; we see how her brother walking by her side is looking proudly upwards at his lantern. We think that we "see" all this. Let us, however, cover up everything else except the heads of these three figures. We then only see a few lines which we cannot understand. Look at what remains of the little girl at the left if we cover her head. Again just a few patches of light. But taken all together, these make up a figure. Or cover up the lantern that the boy is carrying, and we no longer see that he is looking upwards.

The puzzle is very easily solved. The patches of white are chosen by the artist, so that ideas previously gained associate themselves with the sensations that arise by looking at these white patches. With the help of these associations the impression is apprehended, understood, and given a meaning. This process is called assimilation. As long as no ideas from memory associate themselves with the new sensations, the new impression cannot be understood. We do not know what to do with it.

Exactly the same thing happens if a picture of reality presents itself, if we were to see the procession of children itself. It is absolutely impossible for us really to take up all the infinite number of single sensations and feelings which thereby arise. Only a few impressions are picked out by the function of attention, and to these, ideas that are well known to us are associated (children, lanterns, light and shade relations, &c.). By means of these assimilating ideas we complete the act of apprehension.

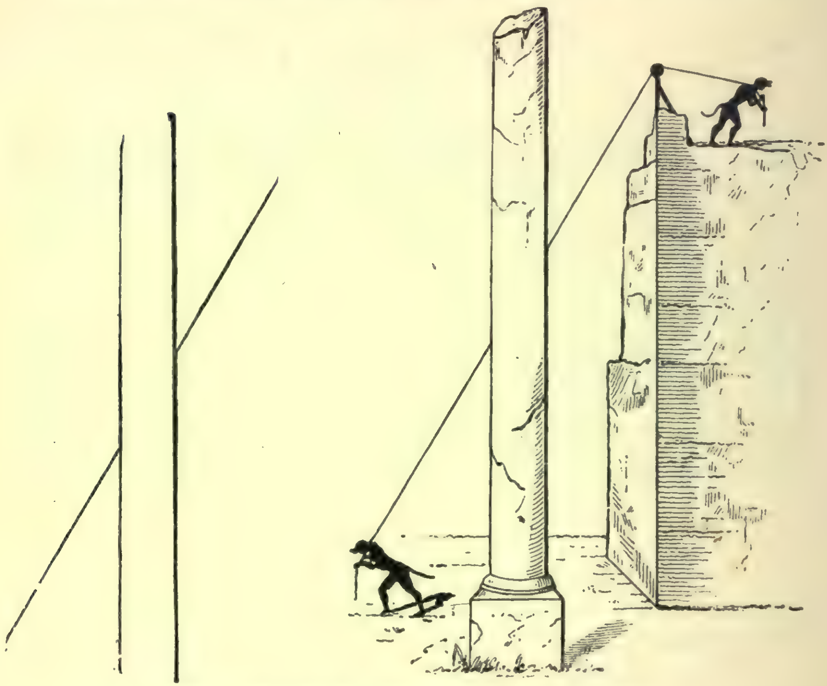
FIG. 183.—Assimilating activity when looking at a picture.

(From *Neue Bahnen.* Voigtländer.)

We no longer take the trouble to look at every detail of the picture; we supply what is wanting out of our previously obtained ideas. In this way the process of apprehension is greatly shortened. For we can work much quicker with memory images than if each act of apprehension required the help of a thorough analysis of all the details of the compound idea. Only with the help of the process of assimilation is it possible for us to deal with the infinite number of stimuli that keep crowding upon us. Without assimilating ideas we would stand before the impressions of our environment just as helpless as a blind man who suddenly recovers his sight.

The association of new impressions with previous ideas takes place so quickly that we do not notice it. We think that we really "see" everything, and do not notice that we add nine-tenths, if not more, out of our previous store of ideas.

We only become slightly aware of this peculiarity of



FIGS. 184 and 185.—Assimilating power of an idea.

(From Schumann, *Zeitschrift für Psychologie*, XXXVI. Barth.)

the process of apprehension, when the assimilating power of our previous ideas is particularly strong, and when we have an opportunity afterwards of comparing the new idea gained by means of assimilation with its original (the stimulus). We say then that we have "misunderstood," "mis-read," &c., and never think that really all

hearing is a "misunderstanding," and all reading a "misreading," or at least a "hearing into" and a "reading into" the stimulus of our own ideas. This sheds a new light upon the saying, "to err is human."

The pedagogical importance of assimilation can be summed up as follows :—

1. The stronger the assimilating activity is, the easier is the reception of new ideas, but the more easily will these new ideas be altered and wrongly apperceived.
2. The richer the store of previously received ideas is, the sooner will an adequate apprehension follow, *i.e.* really corresponding to the new stimuli that are at work.

We can convince ourselves of the great power of assimilation by a little experiment. Fig. 184 shows a well-known illusion—a line intercepted by two parallel lines. The left half of the line appears no longer to be a continuation of the right half, and we cannot get rid of this illusion.

If, however, we draw a picture round it as in Fig. 185, and hold fast to the idea that the two figures are pulling at the rope, the illusion immediately disappears.

The power of the previously received idea, that a rope pulled by two people makes a straight line, is so strong, that the illusion is at once overcome.

2. Reading Experiments with the Tachistoscope

Assimilation is very marked in all cases where it is necessary to grasp a number of elements quickly together and form a compound idea, *e.g.* in reading.

Many a teacher of young children asks himself despairingly, how is it possible to read "rake" for "rose"? His complaints as to the terrible inattentiveness of his pupils would soon stop, if he once took part in reading experiments with the tachistoscope.

He might then make the surprising discovery[1] that with a very short exposition time (2σ or ·002 sec.) some children could apprehend a larger number of letters (not arranged so as to make sense) than he himself could. Professor Meumann could apprehend from three to five letters, an eleven-year-old boy from five to seven letters. Our teacher would also find that, if longer words were exposed, he would make the same kind of mistakes which he considers incomprehensible in children.

Experiments with words making sense have shown that there are two types of readers among adults. The one is marked by fixating, the other by fluctuating attention. The people with fixating attention always keep their attention fixed on a certain spot during the exposure (which need not be the fixation-point on the screen nor even the fixation-point of the eye), and they read a few letters that appear around this spot fairly accurately. If the same word is shown many times successively, the whole is gradually put together like a mosaic, bit by bit (the objective type).

People with fluctuating attention let their attention roam over the whole field of vision; they apprehend a great deal, but they are not so accurate (the subjective type). With these people the process of assimilation is especially strong.

Messmer exposed the word "Kastanienverkäufer" many times in succession and obtained from two different

[1] Compare Messmer, O., *Zur Psychologie des Lesens bei Kindern und Erwachsenen. Archiv für die gesamte Psychologie.* Bd. II., 1904.

observers the following results. (The figures denote the number of the exposition.)

Objective Type.	Subjective Type.
2. (herunter).	1. Kleinverkäuferin.
3. käufer.	2. Kleinverkäufer.
4. verkäufer.	4. Kannenverkäufer.
5. astanienverkäufer.	5. Kastanienverkäufer.
6. Kastanienverkäufer.	

We see here that the subjective type employs the same method as the child often does. The elements he may apprehend act as a cue to call up an idea out of his store of words, which he thinks is the word he has seen, but which often only bears a faint resemblance to the word exposed. The same process is, of course, not absolutely impossible with objective readers, as we see in the example above (herunter).

Children belong mostly to the fluctuating type.[1] Their scope of attention is fairly large. They are, of course, at a drawback in comparison to adults in experiments with words that make sense, since their store of ideas is much more limited. Especially is this so when they have read into the letters a certain wrong word. Adults because of their richer store of words have always new ideas at hand which step in at a new exposure and correct an error. But the child is not so well provided, and one wrong assimilation may have a disastrous effect. The small store of ideas has no power against the assimilating idea which is uppermost. This one idea controls all further apprehension. It perseveres in consciousness. The following experiment with a child shows this clearly.

[1] There are however cases of very strong fixation among even very young children, as experiments made by myself have shown—Untersuchungen über die Aufmerksamkeitsformen beim Lesen und Reagieren.—*Translator's Note.*

The word exposed was "herrschsüchtig." The perseverance of "heran" is striking :—

1. herrschen.	6. heranschütten.	13. hartaschütting.
2. heranziehen.	7. heranschütting.	17. herrensüchtig.
3. heranstürmen.	8. heranschübten.	18. hansüchtig.
4. heranschülung.	9. heranschlüning.	19. hanssüchtig.
5. heranschüning.	12. heranschütting.	24. herrschsüchtig.

The adults were at a drawback when a verb was written with a capital letter as if it were a substantive.[1]

For the verb "Nennet," adults read—Nenner, Neumond, Norden, Name, Nautier, Moment, Neuheit—all of which are substantives. The capital letter sufficed to send the assimilating activity to their store of substantives, and therefore in this case to make the real apprehension more difficult. Children were not so disturbed by this word. Their assimilating power does not yet possess grammatical or orthographical categories.[2]

Tachistoscopical reading experiments show the teacher the cause of errors in reading, and thus give him the opportunity of preventing them. He must try to help the fixating form of attention, and, above all, he must choose reading-matter with words well known to the child. If he does not do this, he is demanding of the child what an adult cannot do. No adult is able to repeat correctly even one sentence of a language foreign to him, after it has been once read over to him, even if no phonetical difficulties are present, for the simple reason that assimilating ideas are wanting.

[1] In the German language all substantives are habitually written with capital letters.—*Translator's Note.*

[2] These experiments are taken from Messmer (see note, p. 214).

3. Quantitative Determination of the Power of Assimilation

Heilbronner [1] tested the apperception of the insane by showing them pictures, first of all in the rough outline, and then gradually filled in (Fig. 186), and by asking them what the picture represented. The same method was used with children by van der Torren (14,450 separate

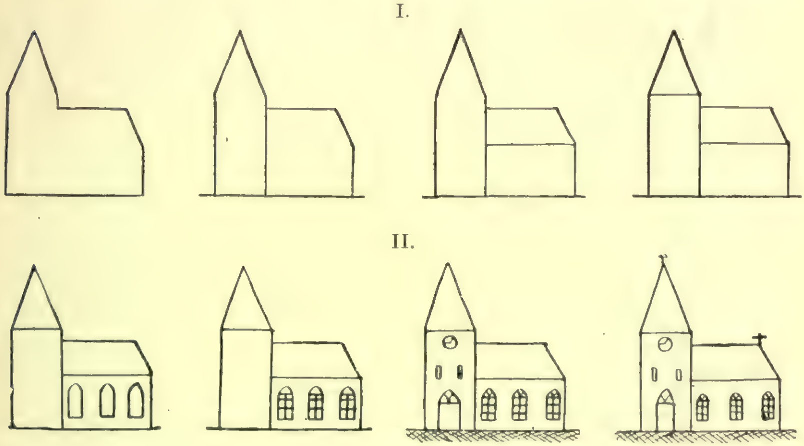


Fig. 186.—Pictures for assimilation experiments, according to van der Torren.

experiments). These experiments showed that boys assimilate on the whole better than girls. With girls it often happened that they did not know what the picture was meant to represent, and therefore did not answer, or when asked said, "I don't know." Considering the assimilations that were made, it was seen that the boys were superior to the girls in regard to the number of correct assimilations at all ages. Of 100 judgments of four-year-old boys about 40 were almost right, but only 20

[1] Heilbronner, K., *Zur klinisch-psychologischen Untersuchungstechnik, Monatschrift für Psychiatrie und Neurologie.* Bd. 17.

of those of the four-year-old girls, and so on. The twelve-year-old girls gave about as many correct judgments (55) as the seven-year-old boys. The girls excel the boys at all ages in "confabulation," *i.e.* in fantastical, erroneous judgments. The four-year-old boys gave 50 erroneous judgments, the girls 70.

Another method is to show the children a complicated picture (Fig. 187), and after taking the picture away to let them describe the objects represented on it. We can also ask about special objects. We first of all demand an "account," and then we arrange a "cross-examination." Here, of course, factors of memory are included, but still assimilation plays the greatest part. By asking suitable questions (leading questions) we set the assimilation to work again, and it often works so strongly that it assimilates things that were not on the picture at all.

FIG. 187.—"Peasants in Cornfield," by Thoma.

(Breitkopf and Härtel.)

For example I asked my pupils the following questions in regard to the picture on Fig. 187 :—

1. Were there many or few birds in the air ?
2. Had not the woman a straw hat on ?
3. Was the dog running in front or behind ?

Out of 42 pupils 13 had seen the birds, 6 the straw hat, and 13 saw the dog, and 8 times he was running in front and 5 times behind. And previously I had discussed several pictures in the same way with them. They knew

exactly what I wanted to get at. They were girls of 8 years.[1]

More important is the question as to how we can influence and educate the power of assimilation. Marie Dürr-Borst[2] conducted experiments for this purpose. She practised the children before showing them the picture in naming colours (she was dealing with coloured pictures). By this means a store of ideas for the purpose of assimilation was obtained and the apperception was improved.

This method could be extended and be used in those cases where we wish to decide what success can be achieved by laying the way for an object that is going to be shown to the children.

With both the methods described a very great number of experiments have to be made, since in each single case the whole field of ideas that the child has already obtained comes into activity. This, of course, opens the door wide to chance. With these methods we can also never arrive at an accurate measure of the power of assimilation that can be expressed in figures.

I should therefore like to recommend a third method that has never yet been used. The assimilating power of one special idea can be tested. We can investigate as to how far up the left part of the slanting line in Fig. 184 must be moved, so as just to appear a continuation of the right part. We thus obtain the extent of variation of this optical illusion for the observer in question. We

[1] I was prompted to make the experiments by a question from the law-courts as to the trustworthiness of a certain pupil, who, as witness, was giving evidence against her stepfather. I had only had this pupil for a short time in my class. The experiments showed that the child was very easily influenced by suggestion.

[2] Dürr-Borst, Marie, *Die Erziehung der Aussage und Anschauung des Schulkindes. Die experimentelle Pädagogik.* Bd. III., 1906.

then make the same experiment, this time by using an assimilating idea (Fig. 185). This time we move gradually upwards and downwards the left part of the rope and the figure that is pulling, until we determine within what limits the line appears as one line. Because of the assimilating power of the idea of a rope being pulled, the extent of variation will very likely be greater than in the previous case. A comparison of the two extents of variation will give an accurate measure of the assimilating power of the observer.

4. The Effects of Assimilation in different Subjects of Instruction

Take any picture, say that of a horse; put it before the children, and tell them to give an account of it. This account will certainly differ according to the teacher, say of natural history or of drawing, who placed the picture before them. The fact that the examination of the objects takes place in connection with a certain subject of instruction calls forth certain groups of ideas in the child's mind, which are held in readiness for purposes of assimilation. We can assure ourselves by questioning, that the children do not mention the colours and forms only for the sake of pleasing the drawing-teacher, and that they do not mention the rest, that they have observed, because it does not interest the drawing-teacher. It is really true that in the one case they apperceive the elements belonging to natural history better, and in the other the colours and forms of the object.

But there must surely be, besides this one-sided apperception, a natural apperception in which the whole mass of ideas, the "Weltanschauung," so to say, of the child, takes part in the process of assimilation. Which subject of instruction cultivates this natural apperception? In

the lower classes, perhaps, the object lesson; in the upper classes such a "universal" subject has remained an ideal. It is unfortunately the case that at ten o'clock, after the first lesson, the child must pull himself together to hold in readiness the ideas that in the second lesson will alone find recognition as assimilating ideas, for in the previous lesson quite different ideas were honoured and demanded in assimilation.

It would be interesting to find out how the natural apperception of older children stands in relation to what is taught them in school by means of a system of special subjects. This natural apperception would have to be tested at home by parents or relatives. Perhaps such experiments would show that the natural apperception of many an exemplary scholar is worse than that of many a child who is poor at school-work, the kind of child who later gets on so well in the world, to the surprise of everybody.

Experiments could also be carried out as to the power of assimilation according to the method employed in a special subject.

We could, for example, take an object of natural history, say the cat, and let the children regard it from the three following points of view and then ask them to give accounts.

1. In general. "Look at the picture properly. We are going to describe it afterwards."
2. The cat as a beast of prey.
3. The cat as a domestic animal.

The first point of view demands a general, systematic description. The second and third demand the influence of special assimilating ideas. The second takes the standpoint of natural history, and the third takes more the standpoint of society, the use of the cat in society.

A comparison between the accounts of 2 and 3 would be especially interesting. It would be important to determine at what age better accounts of 2 or 3 are given.

II. ASSIMILATION CAUSED BY THE FORMAL RELATIONS OF IDEAS

1. Individual Differences in arranging the Spatial Image

Just as each new idea must arrange itself in the temporal succession of the processes of consciousness, similarly I can only assimilate a new sight idea, or image, by arranging it in the idea of space that I have obtained by much experience.

Here we find many individual differences according as the forms of spatial ideas that have been obtained, *i.e.* ideas of right and left, above and below, or of special forms such as the semicircle, &c., work strongly or weakly as assimilating ideas.

Albien [1] showed the drawing in Fig. 188 for ten seconds to various pupils and then let them draw it. One pupil (Figs. 189, 190) belongs to the visual type. He has not recognised everything in the first attempt (Fig. 189), but all that he has drawn is fairly correct. In the second attempt the whole drawing is correct. Only the semicircle is imperfect. The pupil relies entirely on his eye. He reproduces the round form, without bringing any of his ideas to bear on the picture. If he had done so, he might have recognised that the curve is a semicircle.

The second pupil is quite different. He comes to the figure with a store of forms that he has learned, and therefore he assimilates more quickly. Even in the first attempt (Fig. 191) he has represented everything.

[1] Albien, Dr. G., *Zeitschrift für experimentelle Pädagogik.* Bd. VI., 1907.

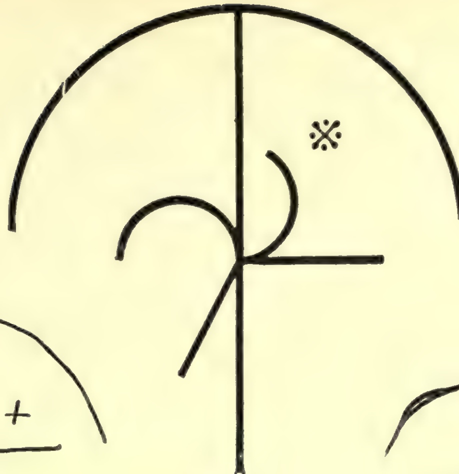


FIG. 188.

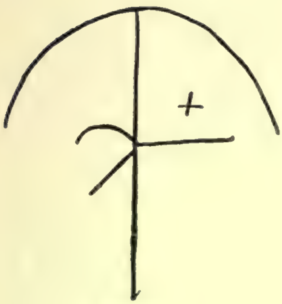


FIG. 189.

FIG. 190.

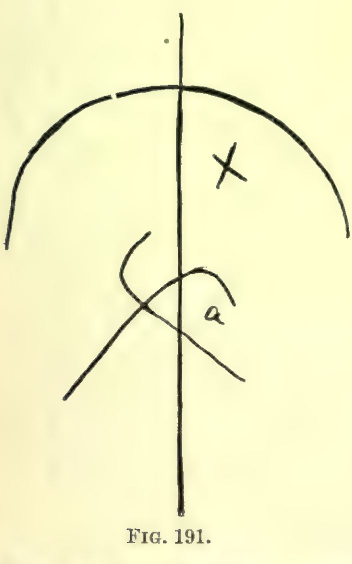


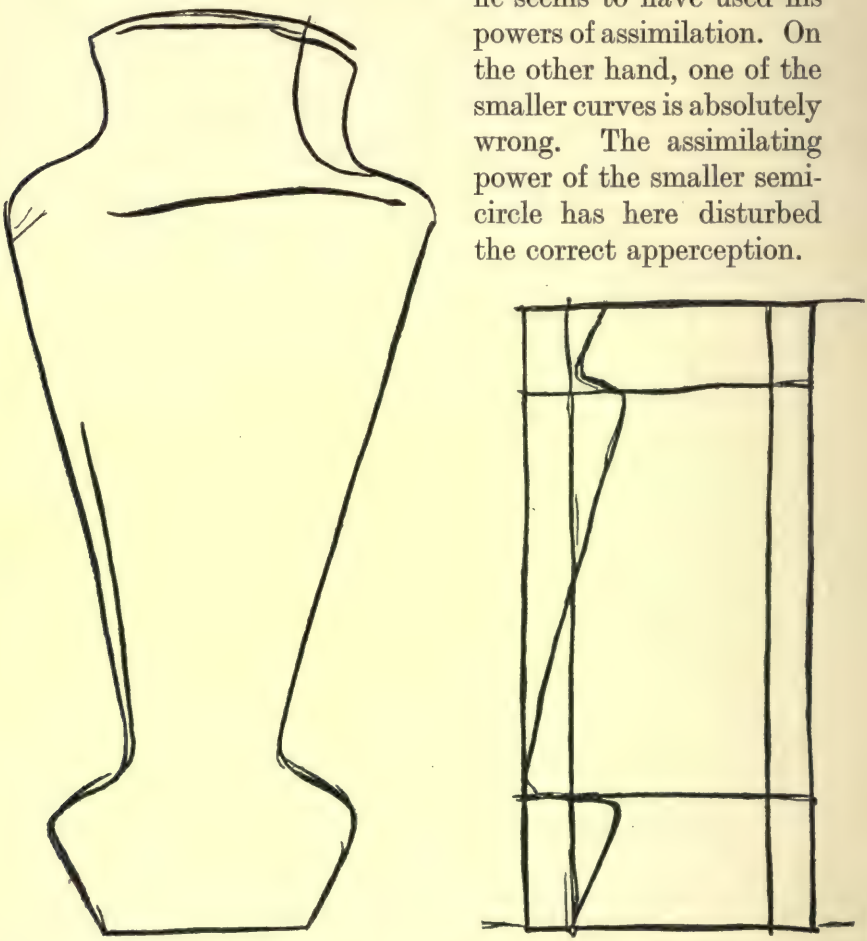
FIG. 191.

FIG. 192.

FIGS. 188–192.—Drawings by two pupils, showing visual and constructive types. 188. Copy. 189. First drawing by a pupil of the visual type. 190. Second drawing by the same. 191. First drawing by a pupil of the constructive type. 192. Second drawing by the same.

(From Albien, *Zeitschrift für experimentelle Pädagogik*, VI).

But in the second attempt (Fig. 192) there are still considerable mistakes. The circle is certainly better reproduced, as he seems to have used his powers of assimilation. On the other hand, one of the smaller curves is absolutely wrong. The assimilating power of the smaller semicircle has here disturbed the correct apperception.



FIGS. 193 and 194.—Drawing of a vase by two pupils. 1st. Visual type. 2nd. Constructive type.

(From Albien, as in Fig. 188.)

The two pupils will, of course, work quite differently. They are given a vase to sketch. In a short time the first is ready with a sketch (Fig. 193), while the second has only

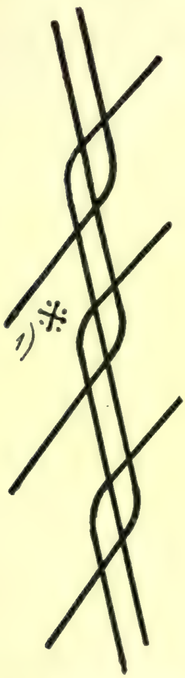
made his preparations (Fig. 194). He has made a diagram, into which he can draw the form.

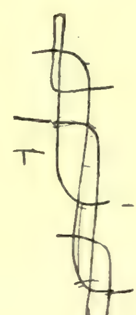
2. Anomalies in Apperception

Even in the experiment described, a case of confounding right and left occurs. Any new form that

Fig. 195. Drawing of the copy shown in Fig. 188.

(From Albien, as in Fig. 188.)





Figs. 196 and 197.—Drawing from memory a diagram as if seen in a mirror. 196. Copy. 197. Drawing from memory.

(From Albien, as in Fig. 188.)

occurs must at all costs be arranged in the space at disposal, and if at one point a small mistake should be made, it can lead ultimately to an inversion of the whole form, in order that this one mistaken form should be correctly represented. One of Albien's pupils

turned the whole figure 90° round (Fig. 195), another drew Fig. 196 fairly correctly, but was very much

FIG. 198.—Confusion of side and bird's-eye view in a child's drawing. (From Levinstein, *Kinderzeichnungen.* Voigtländer.)

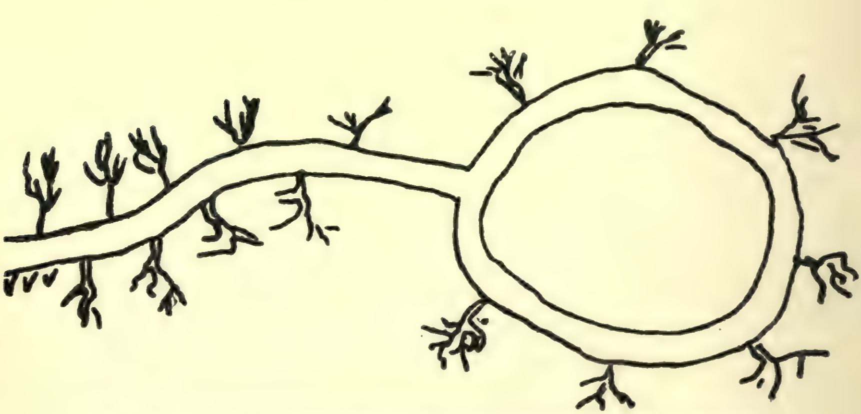


FIG. 199.—The same confusion of side and bird's-eye view in a drawing by a Dakota Indian. Pond and road bordered by trees.

(From Levinstein, as in Fig. 198.)

astonished to find that he had drawn its mirror-image (Fig. 197).

A similar anomaly is seen when children in the same

FIG. 200.—The same confusion as in Figs. 198–9. Drawing from an Egyptian grave. Pond with trees and brick-workers drawing water.

(From Levinstein, as in Fig. 198.)

FIG. 201.

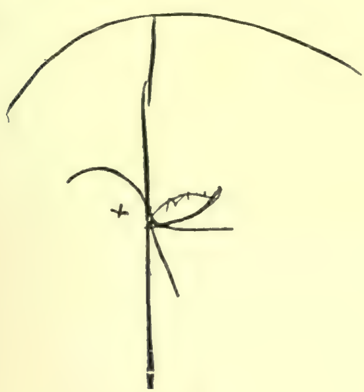


FIG. 202.

FIG. 203.

FIGS. 201–203.—Persevering ideas as distractions of perception.

(From Albien, as in Fig. 188.)

drawing use the two different possibilities of representation, the bird's-eye view and the side view (Fig. 198). The child does not think that it is against the laws of

sense to use a different system of assimilating spatial ideas in order to fill up his picture. Pictures drawn by peoples on a lower stage of culture are often similar (Figs. 199, 200). We conclude with an example out of Albien's experiments, where not a pure spatial idea but the idea of an object exerted its influence, and where the apperception was made more difficult owing to the perseverance of this idea. The pupil had carried out the test fairly well in his three attempts (Figs. 201, 202, 203). The semicircle is, however, conspicuously flat. When he was asked, he said he had thought of a cross-bow, when looking at the picture.

CHAPTER VIII

THE MEMORY

I. THE UNDERLYING PRINCIPLES IN METHODS OF MEMORY EXPERIMENTS

1. Classification of Methods of Memory Investigation

Memory [1] is generally defined as the faculty of storing ideas in order to reproduce them after a certain time. This popular explanation contains two elementary errors. We cannot speak of storing ideas. Each single process of consciousness, which we experience, is irreparably lost after it has passed. It will never return. Therefore we can only mean that ideas or elements of the process of consciousness come back again in a similar manner. Secondly, the popular definition overlooks the fact that memory is essentially a phenomenon of successive association. It is never concerned with one idea or with one element of our consciousness, but always with two such elements, which were bound together by one act, by the process of learning. The one element, when it reappears either as external or internal stimulus, *i.e.* as a sensation or as a reproduced sensation, associates the other element,

[1] The logical connection between this chapter on memory and the previous one on assimilation is not very great. But we have already mentioned in our introduction that we do not intend to give a whole system of psychology. Therefore we have only dealt with assimilations out of the class of simultaneous associations, omitting fusions and complications (see Wundt.) Out of successive associations we choose the complicated phenomenon of Memory, because it is of great importance for pedagogy and because the method of memory experiments is especially well developed.

which is similar to the one which has been bound to it by the process of learning. This last process is called reproduction. There is generally a feeling connected with this—a feeling of recognition. If, for example, I reproduce $3 \times 4 = 12$, I recognise that it is correct.

In testing the memory I can use a method which appeals to this feeling of recognition. I can investigate within what limits I may change a previously given stimulus, say a colour sensation, so that it may still give rise to a feeling of recognition. Let us call these methods "methods of recognition."

We can, however, also make use of the reproduction. The child must repeat to-morrow, what he has learnt to-day.

Our methods can therefore be divided into two classes—those of recognition, and those of reproduction.

2. The Material in Memory Tests

The phenomenon of memory shows itself in its simplest form in the binding together of two elements of consciousness. In practical life, and especially in pedagogy, the successive binding together of many elements in rows plays so great a part, that the investigation of memory has paid special attention to the laws which govern this binding together in rows.

Of the greatest importance are rows of words, such as we find in the reproduction of our ideas by speech. The discovery of the laws, which govern the acquisition and reproduction of such complicated rows, must be looked upon as the aim of memory investigation.

The experimental method can already show good results here. It has been fairly well established by experiments that shorter texts, say poems, can be best imprinted on the memory by going over them as a whole,

and not by dividing them up in parts and then by memorising each part separately. The psychological explanation of this is simple. If I read over a verse of a poem five times in succession, then the last word of the verse is always followed by the first word of the same verse, and unconsciously associations between the two are formed. We cannot wonder, then, that in such a case the numerous false associations often disturb the whole reproduction. Every time at the end of a verse the reproduction is hampered. An investigation with complicated continuous passages has, of course, great difficulties. It is really impossible to find two poems which can be called exactly equally difficult to memorise. By such a method we can never arrive at figures to denote the power of memory.

To attain this we must find some material that is constant, that we can measure as to its difficulty. The idea of using letters or figures at once arises. But we soon find that we have not enough single elements to put our rows together. The single letter comes round again too often.

Out of many thousands of experiments, nonsense syllables of the form, sil, tel, mab, &c., have proved the best. A vowel is placed between two consonants. Any such combination that makes sense must be rejected, because a word making sense can naturally be more easily associated with the following syllable, than a nonsense syllable.

After making tests with the help of such syllables we can then proceed to words, sentences, and whole passages.

3. The Variable Conditions in Testing the Memory

(a) *Learning.*

We can present our memory material in different ways. I can read out my row of syllables or show them

in written or printed form to the child, *i.e.* acoustical or visual exposition. I may allow the child to repeat the syllables to himself or aloud, *i.e.* acoustical-motor and visual-motor exposition. I could also allow the letters to be traced by the hand in the air or on a paper, &c., and then determine what effect this method of exposition has on the memory. Such experiments could give valuable help as to the correct method of teaching writing.

Two things must be specially noted in such experiments. The time of exposition must be the same in all cases we wish to use for comparison. If in one case we write down a word, and in another only see it for a moment, of course the writing down will give better results. In an accurate experiment the time of writing and of seeing must be exactly the same. Secondly, it is important for pedagogy that the tests should not follow too soon after the learning. We are more interested as to whether lasting retention loses or gains in a special case.

If we wish to test the memory in general, a visual exposition is to be recommended. It is impossible to attain absolute evenness in acoustical exposition, *i.e.* to read the words out with equal clearness, loudness, and emphasis. In showing printed syllables a perfect unformity is more easily attained. The time of such an exposition can also be much more accurately regulated.

As regards an investigation of the memory for forms, some systematical work is badly needed, *e.g.* one dealing with the influence on the memory of different ways of presenting one form—showing the form, drawing the form, modelling it, &c., and then doing the same things from memory—describing, drawing, or modelling the form.

What visual memory can achieve by practice even with young children can be seen in Fig. 204, and in Fig. 205 we see the beginnings of such an investigation

as we have proposed. No. 3 shows a drawing from memory after previous copying, No. 4 after previous modelling.

In the process of learning we can vary the following conditions.

The number of repetitions. I can test how the memory is affected according as I show a row once, twice, &c.

FIG. 204.—Productions of the visual memory of young children.

(From Tadd, *Neue Wege zur künstlerischen Erziehung.* Voigtländer.)

The rapidity of the exposition. I can show each object or syllable for half a second, a whole second, and so on.

The interval between the expositions. I can repeat a row twenty times in succession, or between each repetition I can make a pause of an hour, a day, a week, &c.

Lastly, I can test different accessories, *e.g.* the position, the colour, the environment of the stimuli. Does the child learn easier if the syllables stand in rows one under the other or one next to the other, if the letters are black or coloured, if the background is grey or white?

If I choose one such factor as the object of my test, then all the other conditions must remain unchanged.

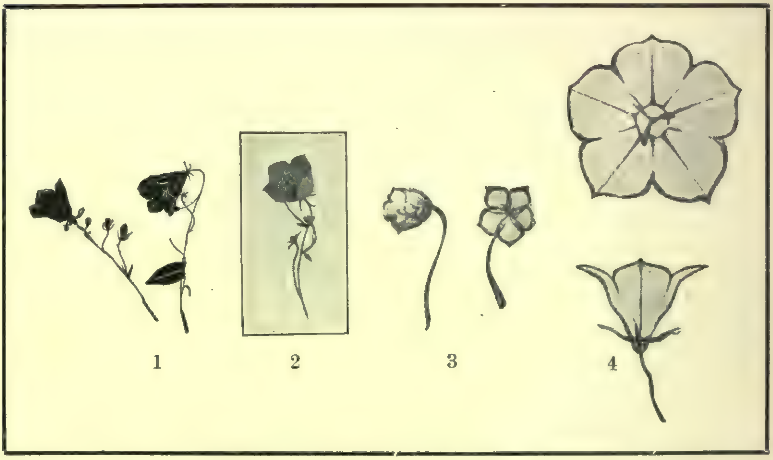


FIG. 205.—Drawings of a bluebell. (Walter S., age 12½.) 1. Silhouettes from nature. 2. Coloured chalk-drawing from nature. 3. Drawing from memory before modelling the flower. 4. Drawing from memory after modelling the flower.

(From Weissenborn, *Neue Bahnen*, 1906. Voigtländer.)

If I vary the colour, the number of repetitions, the rapidity, the way of exposition (visual or acoustical), the interval between the repetitions and all other accessories must remain constant.

(b) *The Interval between Learning and Reproducing.*

This can be varied first of all as to length. I can test how much of a row I can reproduce after an hour, a day, or a week. With smaller intervals I can work with

"empty" or "filled out" times. I can ask how the memory is affected when the interval is filled with certain mental work (say arithmetic), or when it is filled with "doing nothing."

(c) *Reproduction.*

This can also be varied in many ways. I can let the reproduction follow in speech or in writing. The time factor is here very important. In an exact investigation, each syllable should have a certain time for reproduction, from two to four seconds. Only what is reproduced during this time should be reckoned. The greatest difference, however, is, as to whether I demand a reproduction or merely the presence of the feeling of recognition (recognition and reproduction methods). This difference will be considered more fully in dealing with the different methods.

FIG. 206.—Ranschburg's memory apparatus.

II. APPARATUS FOR TESTING THE MEMORY

1. FOR PSYCHOLOGICAL INVESTIGATIONS

Ranschburg's apparatus consists of a box in which a cross-bar moves with equal jerks by means of two electromagnets (Fig. 206). On the cross-bar is a disc (Fig. 207) with the words so arranged that only one word can be seen at once through the slit in the cover of the box

(Fig. 208). If I connect the apparatus with a metronome, the disc jerks one word further at each beat of the metronome. Each word appears in the opening for any

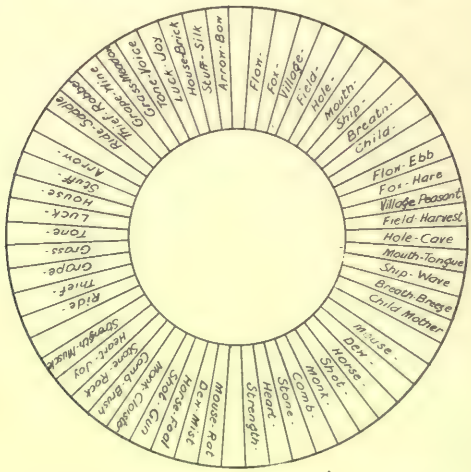


FIG. 207.—Disc for memory experiments.

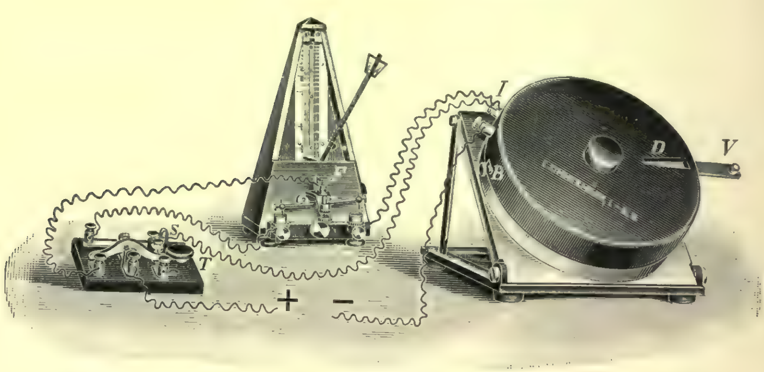


FIG. 208.—Ranschburg's memory apparatus arranged for an experiment.

required time. If I wish to expose the row more quickly I push the weight on the metronome down lower. It beats quicker, and therefore the circuit which sets the electro-magnets into action is closed more often. If I wish to show a row of seven syllables, I press down the

contact T (Fig. 208) until the metronome has made seven beats. Then I let go the contact and the current is broken. The disc remains stationary, although the metronome continues beating. If I wish to introduce a pause between two syllables, I insert a blank between the syllables on the disc. The noise of this apparatus when in motion acts as a disturbing element.

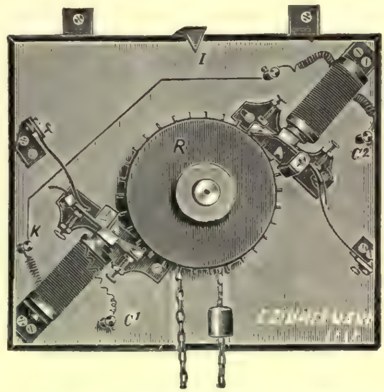
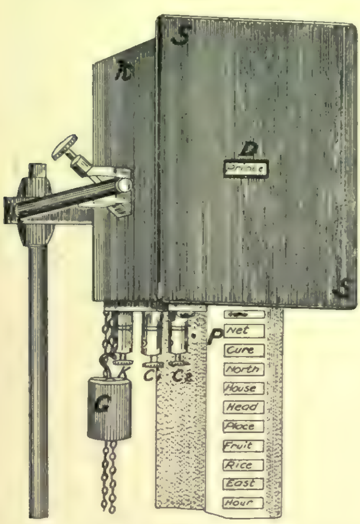
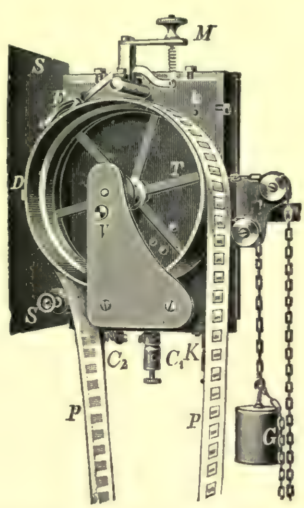


FIG. 209.—Wirth's memory apparatus.

Professor Wirth improved this apparatus and got rid of the noise. Fig. 209 shows Wirth's apparatus, which is capital for





FIGS. 210 and 211.—Wirth's memory apparatus with long paper strips.

all laboratory experiments. We see the two electromagnets with their anchors, past which the crownwheel moves in jerks. Figs. 210 and 211 show a similar

apparatus, but here a long strip of paper is used instead of a disc. This has the advantage that as many syllables as desired can be exposed in succession.

Professors Schumann and Meumann used a clockwork with a drum (a kymograph). In front of the drum was a screen with an opening (Fig. 212). The syllables were written or printed on a paper that was pasted on

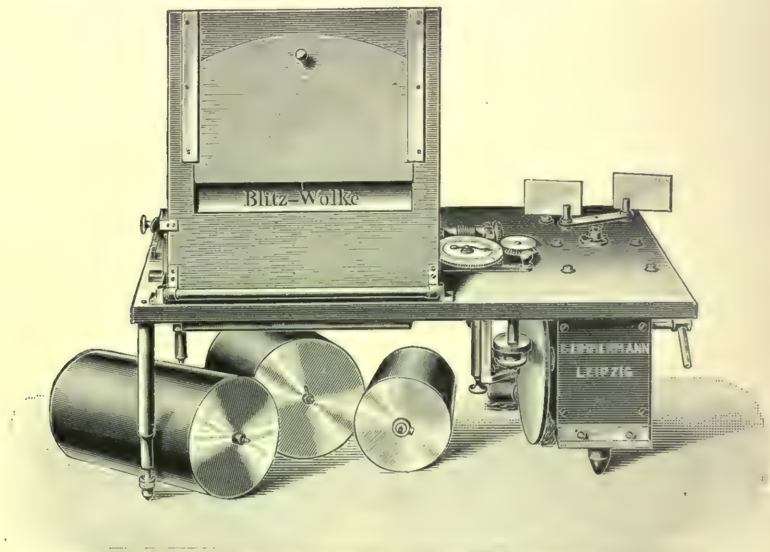


FIG. 212.—Müller's memory apparatus.

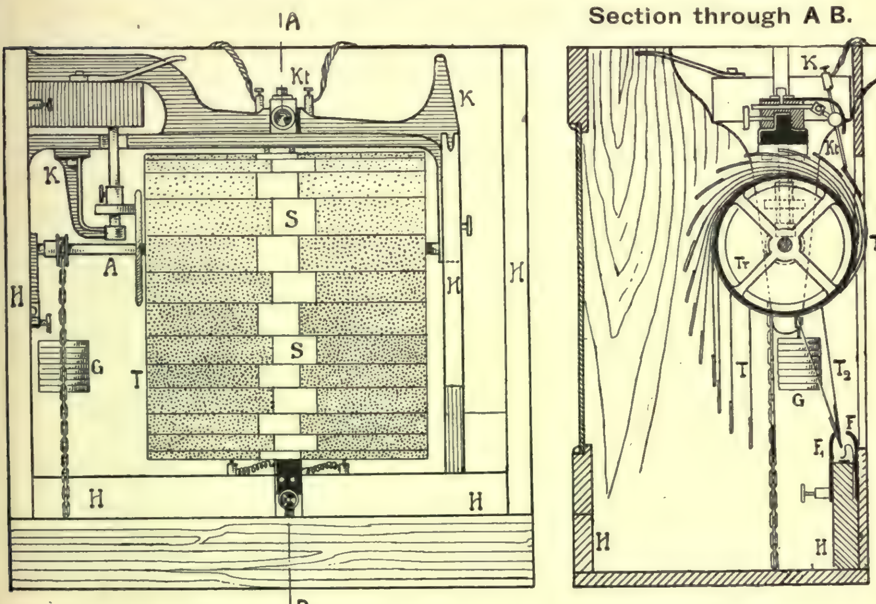
the drum. By using this apparatus at high speeds, cases of slight dizziness were noticed. It is certainly not an advantage for the exposed object to be continually in motion.

2. For Pedagogical Investigations

For pedagogical investigations we demand two things. The apparatus must be simple, and the object must be able to be seen from a distance.

I advise, therefore, the following arrangement. We use

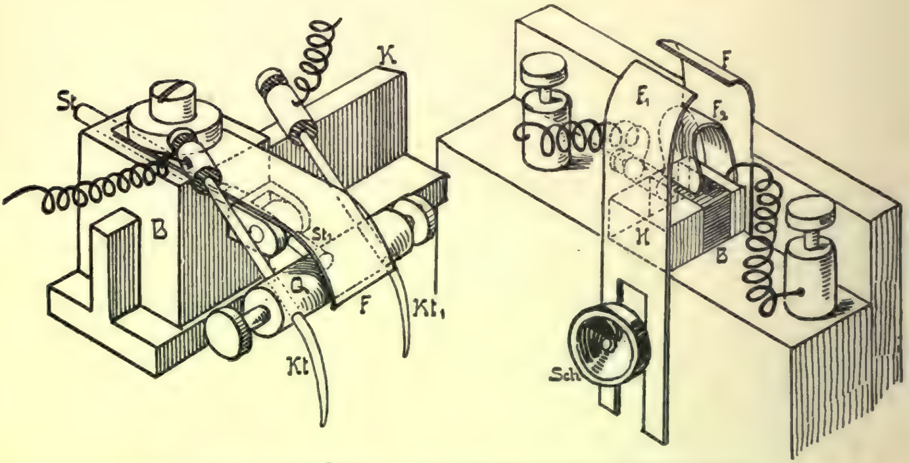
our ordinary kymograph (K) with clockwork (Fig. 144), which is this time placed in a horizontal position in a wooden box H (Figs. 213 and 214). On the drum T_r a long band is fixed, on which hang separate pieces of paper T, T_1, T_2, each one centimetre longer than the other, lying on each other and so arranged with holders at the lower end of each paper that we can insert strips of



FIGS. 213 and 214.—New memory apparatus for pedagogical experiments.

paper with the syllables. When the drum is set in motion, each piece of paper with its syllable falls down, one after another (Fig. 217). It is the same idea that is used in some cinematographic apparatus, where a thick book of pictures flashes past. Our apparatus works, of course, much slower. The rapidity can be varied according as we let the drum go quicker or slower. With this apparatus a hundred or more people can be tested at the same time. It is also very convenient to transport.

To measure the reaction time to a word the electrical contacts (K*t*) can be used. Fig. 215 shows the upper and Fig. 216 the lower contact. Generally the upper contact



FIGS. 215 and 216.—The upper and lower contacts of the new memory apparatus.

is sufficient. The apparatus can therefore be used for the purpose of measuring the reaction time to an optical stimulus (see p. 173).

III. METHODS OF RECOGNITION

1. SINGLE COMBINATION

(a) *Test by means of Stimuli with continuous Changes.*

Recognition methods investigate by how much an idea has changed after a certain time. For these tests I therefore do best to make use of stimuli, where continuous changes can be effected, *e.g.* a colour, say a certain blue of 180° blue and 180° grey on the colour-mixer. After a minute, an hour, or a day, I show a similar blue (200° blue, 160° grey), and ask if it is the same. The investigation is really one of the difference sensitivity,

FIG. 217.—Testing the memory.

but the stimuli compared are presented at different times. The judgment, however, follows under quite different conditions. Whereas in the real tests of the difference sensitivity a comparison of the two colours takes place as one process, in this case the giving of the judgment depends on the feeling of recognition. According as it is present or not, I give my judgment. We might say that already, in this first method of testing the memory, we contradict our definition of memory. Where are the two elements that at the first exposition are to be joined together?

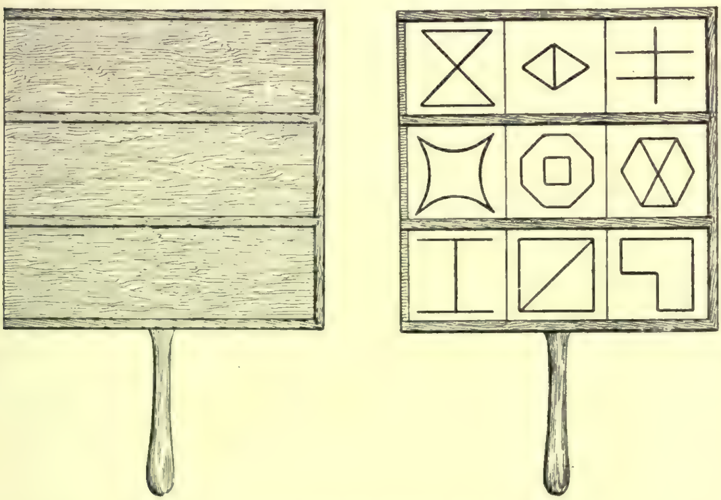
First of all we note that in such experiments the work required of the memory is a minimum. We can easily remember ten or more words, but the memory for a shade of colour does not stretch from here to the other side of the street, where I wish to choose a cloth of a certain colour. With children not very much can be achieved. They may know, the next day, that yesterday they had been shown a blue colour, perhaps a light blue or a dark blue, but not more. You see we get at once the other element of consciousness that is associated with the colour and without which the memory could not work, namely, the word. It is soon noticed that in such experiments, in order to achieve better results, a system of words is built up to form associations with the colours, for example, in testing degrees of brightness—black, greyish-black, dark grey, medium grey, light grey, greyish white, white. By similar means painters develop a memory for colours which to a layman is incomprehensible.

In tests of the difference sensitivity for tones after long intervals, the innervations of the muscles of the larynx act as association elements. Such an innervation often gives rise unconsciously to a soft humming of the tone.

The problem of an absolute memory for tones could be

greatly helped by investigations on children. There has been up to now no indisputable material brought forward to settle the question, whether or to what extent an absolute memory for tones is possible.

As elements of association, first of all the innervation of the laryngeal muscles would be used. On one day the note "a" would be given, and then reproduced once



FIGS. 218 and 219.—Visual objects for testing the power of noticing of the insane, according to Bernstein.

(*Zeitschrift für Psychologie*, 1903. Barth.)

every following day. Out of the total number of errors the middle value would be calculated in the ordinary way, and we could see whether after a certain time the error became smaller.

Elements of association out of more complicated complexes could be used. For example, "Sing the first note of 'Rule Britannia.'" We then proceed as before. Every day the reproduction by the pupil, and then the singing of the right note by the teacher, as an example for the next day.

(b) *Test by means of Stimuli without Continuous Changes.*

Bernstein mentions a simple method of testing the memory of the insane, which might also be used with children.

A small apparatus (Figs. 218 and 219), with objects that can be easily changed, is shown the patient. After a

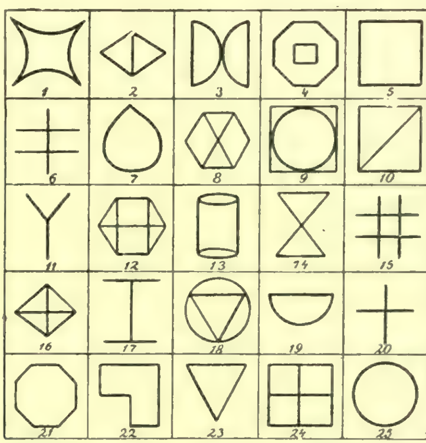


FIG. 220.—Table for testing the power of noticing of the insane, according to Bernstein.

certain time he is shown another table (Fig. 220) which contains the same objects and a great many others. He must now pick out those objects which he thinks have been shown to him before. He will obviously choose those that arouse in him a feeling of recognition. If the idea of an object has changed greatly, he may often choose wrong objects.

This simple method can be used with great profit in testing defective children. It may also help in diagnosing defectiveness.

2. Combination of a Series

(a) *The Method of Recognition.*

With long rows I can also test the power of the memory in regard to the feeling of recognition. I can expose in the memory apparatus a row of eight or twelve syllables. I then show another row which is exactly the same as the first, except for two syllables that have been changed. The observer is asked at each syllable, if he recognises it. From the correctness of his judgments we can draw conclusions as to the excellence of his memory.

Up till now this was the only method that was given the name of a recognition method.

The calculation of the results of a recognition method causes great difficulty. Two errors of quite opposite natures may appear. The observer may say that he recognises a new syllable, or that he does not recognise an old one. It is difficult to bring these two kinds of error under one point of view.

(b) *The Method of identical Rows.*

To make a uniform system of calculation possible, the method of identical rows has been developed by Reuther.[1] The observer is told that in the rows that follow, a syllable here and there is to be altered. He has the task to decide which syllables are old and which new. In reality, however, no syllables are changed. If the observer says "new" to one syllable, it means that the feeling of recognition for that syllable is not yet strong enough. If in a row of eight syllables three such cases appear, we may say that the observer has up till now retained five syllables. Now

[1] Reuther, *Beiträge zur Gedächtnisforschung. Psychologische Studien*, Bd. I., 1906.

and again really new syllables must be added, so that the observer may not discover the method.[1]

Many objections to this method have been raised. Since, however, it has corroborated many important results that have been obtained by other methods, it seems quite a useful method if employed carefully.

Very important was the result obtained by changing the exposition time. The best performance was achieved when each syllable was shown for about ·5 or ·6 secs. Less was noticed with a quicker or slower rate of exposition. This shows that each individual possesses his own rate of learning. By varying the time, the most favourable rate of learning for boys and for girls at all ages could be established.

If the method of identical rows is used in investigations with children we recommend another method (say a reproduction method) to be used as well, as a means of control. And in general it is good to work with two methods at the same time, if there is the slightest doubt about the trustworthiness of the method or the judgments of the observer, and this latter is often the case with children.

If in such a case the two methods give similar results, if they show, for example, the superiority of the memory at certain ages, or in certain classes of society, then we have achieved two things. Both the methods and the judgments of the observers must be considered trustworthy. Such investigations of method are greatly to be desired.

IV. METHODS OF REPRODUCTION

The reproduction methods are generally used to find out the laws of memory in learning rows of words, &c.

[1] Of course, if the observer happens to find out the trick, the experiments must be immediately stopped.

A row of syllables is shown once or oftener, and the observer is asked to repeat the row from memory, by speech or by writing.

A certain number of syllables is then "correctly" reproduced. We have mentioned before that a really correct repetition of the impression is impossible. If, for example, I expose six syllables of the form *lir*, *mab*, *pon*, &c., no person can reproduce these syllables exactly, *i.e.* give all letters according to their height and form, their exact position, the distance from each other, &c. Just as, if syllables are read out, no one can reproduce exactly rhythm, tone, pronunciation, &c. What, therefore, in any particular investigation is to be considered "correct" is determined by some convention, or agreement. The convention in investigations with forms of speech is generally this, that a reproduction is considered correct, if the experimenter can recognise in the spoken sound or written form the three letters in question. If, however, we are testing the memory for form by showing written letters and demanding a written copy of them, we must, of course, demand a certain resemblance to the forms shown.

From this point of view we may also settle the question of errors. If we are once clear as to what we are going to call "right" and what "wrong," it has little sense by means of a complicated system to give each error a certain value, say a fourth, a half, and so on. If we did this, we would have to value the right cases as well, according as they were more or not quite so correct.

We shall therefore only distinguish between right and wrong cases, and this makes the investigation much easier. If a special study of the errors seems desirable, then it is better to choose a division according to quality and not to quantity. A division according to special

kinds may sometimes lead to important psychological and pedagogical results.

1. The Scoring Method[1]

The scoring method is as follows. About twenty-four syllables are read out one after the other, but so that the first, third, &c., are especially emphasised. As a test the experimenter names, say, the seventh syllable, and the observer has from memory to mention the eighth; the experimenter mentions then the twenty-first, and the observer the twenty-second, and so on. The experimenter mentions in irregular order all the emphasised syllables, and the observer has to find the corresponding unemphasised syllable. Here the basal principle of the memory is tested, *i.e.* the association of two elements. The single association can be tested in a purer form, if both the elements are shown together (Fig. 217). When the apparatus turns, the following pairs may for example appear:—

Arzt	tabib.	Meer . . .	deniz.
Kuh . . .	inek.	Gift	zehir.
Nerv . . .	sinir.	Ring . . .	jüzük.[2]

After a pause, only the first word of each pair appears. The task is to reproduce the corresponding word.

The following interesting experiment can be made with such a row. Give no instruction to the children before the experiment. Tell them simply to watch the words. Now let the single words appear. When the first appears, ask, "What word stood under it?" It

[1] Judd calls it the Guessing Method.—*Translator's Note.*

[2] This is taken from Ranschburg. Each pair represents a German word and a corresponding word from a foreign language, which must of course be unknown to the observer. The task is much the same as in learning a vocabulary of foreign words.

will be seen that practically nothing can be reproduced. You will be able to read in the faces of the children—"Oh, you should have told us before, what you meant to do." We see from such an experiment that not only does the attention contribute much in bettering the strength of the memory, but also that it is necessary to know beforehand which two elements are to be bound together. This is an important point for pedagogy.

If we repeat the experiment, the children will notice much more.

The scoring method can also be used to investigate reproduction times. We can measure, with the method described in the next chapter, the time from the exposition of the syllable by the experimenter to the reproduction of the syllable by the observer. The quicker the reproduction follows, the stronger is the association between the two elements.

This method is specially suited for subtle investigations in the laboratory.

2. Method of the Memory Span

The methods that follow are solely for investigating with rows.

The method of the memory span, often used by American psychologists, is very simple. Three syllables, say *len*, *mab*, *lir*, are first shown in the apparatus or read out. They are then reproduced. Then four syllables are given—*fon*, *sum*, *ral*, *dep*—and reproduced. We proceed in this manner, and thus fix how many syllables can be reproduced after one exposition of them.

What we are testing here is not prolonged retention, *i.e.* the real function of the memory, but immediate retention, noticing power. We see this from the haste with which the observer reproduces the syllables. If the

smallest disturbance arises, everything disappears. We have really not tested the memory span, but rather the span of attention—the number of elements that the attention can apprehend at one grasp. We find that generally five, six, or seven syllables can be retained, just as we found in our tachistoscopical reading experiments.

If the attention span of an observer amounts to seven, we find, in giving him a row of eight syllables, that he cannot retain seven, but only five, or even four. With such longer rows the so-called retro-active inhibition makes its appearance.

3. Method of retained Elements

If I have a longer row, say of twelve syllables, the simplest method is to let the child repeat or write down after every exposition of the row what he has retained, paying no special attention to the order of the separate reproductions.

According to this method, Pohlmann[1] investigated the question as to whether a grouped or ungrouped row could be more easily retained. In the ungrouped series of acoustical stimuli, twelve syllables were read out as evenly as possible. In the grouped series the second syllable was slightly emphasised, the fourth strongly, the sixth slightly, and so on. The result is shown in Fig. 221. The grouping (line marked *g*) seems to cause an improvement in retention, and especially of the strongly emphasised syllables.

In the ungrouped series of visual stimuli the twelve syllables were written down in a row on the blackboard; in the grouped series they were written in three rows, four

[1] Pohlmann, A., *Experimentelle Beiträge zur Lehre vom Gedächtnis.* Gerdes and Hödel, Berlin, 1906.

in each row. The grouping helps even more here than

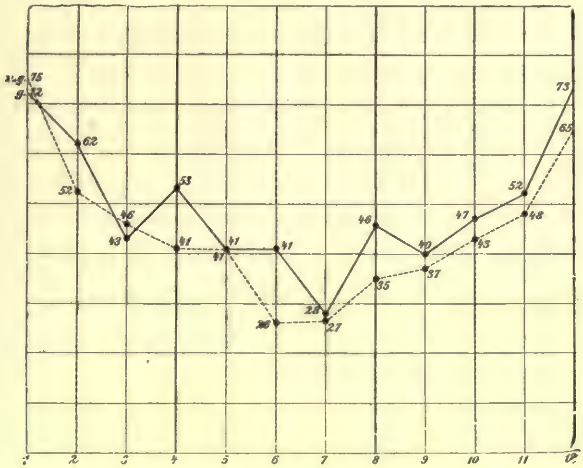


FIG. 221.

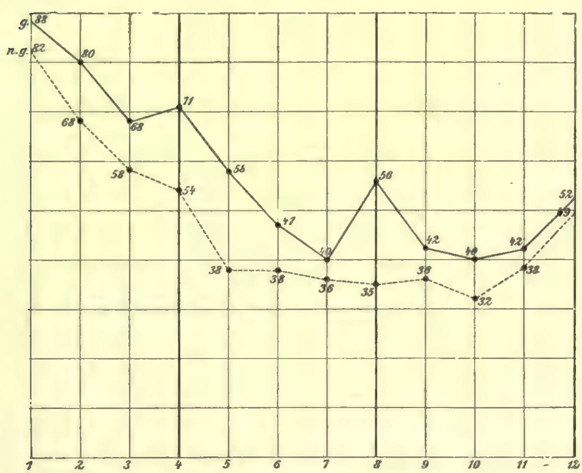


FIG. 222.

FIGS. 221 and 222.—The influence of grouping of rows of twelve syllables on the memory. Acoustical and visual exposition.

(From Lipmann, *Zeitschrift für Psychologie*, XLIV. Barth.)

with acoustical stimuli (Fig. 222). The eighth syllable, for example, is only remembered in 35 cases in the un-

grouped series (the dotted line *n-g*), but in 56 cases in the grouped series.

We see of what importance a sensible grouping is for the memory.

A comparison of the two figures shows further the very different distribution of attention during the acoustical and the visual series. With the acoustical (grouped or ungrouped) the attention easily grasps the first and last syllables, the middle ones are at a disadvantage. In reading out something to be remembered, the teacher must therefore use special means to fix the middle elements in the memory.

In the visual series the memory gradually gets worse from the beginning. Therefore if visual matter has to be learnt, *e.g.* when the children are reading the passage themselves, the teacher must direct most attention to the middle and especially to the end.

4. The Prompting Method

The prompting method, which was introduced by Ebbinghaus, proceeds in this manner. A row is shown to the child. Then it is told to name the first syllable and then the second. If the child cannot remember the second syllable, the experimenter tells him, and he must go on to the third, and so on. Each time he cannot continue, he is prompted. The number of "helps" gives the number of syllables forgotten.

The prompting method has been very seldom used, and therefore has not been so well developed as the other methods. We need not discuss it in detail.

5. The Learning Method

The learning method also originates with Professor Ebbinghaus. In his book *Über das Gedächtnis* (1885)

he established this method, and so began for the first time an experimental investigation of the memory. Even although the method in its details has been further developed, especially by Müller, Schumann, and Pilzecker, yet Ebbinghaus' work is still of the greatest importance, and must be considered as the foundation-stone of all accurate study of the memory. There are few brochures on experimental psychology that are so suited to introduce their readers to the experimental methods as this small volume of Ebbinghaus.

He used, as a measure of the power of the memory, the number of repetitions that are necessary to learn a fairly long row.

He found, for example, that 7 syllables could be learnt after two repetitions, 16 after 30, 24 after 44, 26 after 55 repetitions. The number of repetitions increases very rapidly.

He considered a row as "learned" if it could be repeated once—or twice—without a mistake.

Radossawljewitch investigated with the same method the memories of adults and children, in order to compare them. He used the kymograph (Professor Müller's apparatus).

He exposed a row of eight syllables. The observer was told to say so as soon as he felt he could repeat the row by heart. In these experiments there was a drastic example of the necessity of directing the attention in a special direction in order to achieve the memorising of the syllables.

A foreigner took part in the experiments for the first time. He read the row 20, 30, 40, 46 times. The experimenter then stopped the apparatus and asked him if he did not yet know the row. To which he replied, "What! Must I learn the row by heart?" He had not understood the instructions, and therefore had retained practically

nothing. He then learnt the row with ease after six more repetitions.

6. The Saving Method

If by means of the learning method I learn to-day a row of sixteen syllables, perhaps to-morrow or in a month I shall not be able to repeat them. Perhaps I cannot repeat a single syllable. If, however, I learn the row again, I shall not need as many repetitions as before. If at first thirty repetitions were necessary, perhaps twenty will this time be sufficient. The number of repetitions which I save—in this case ten—can be used as a measure for what still remained in the memory.

The saving method, also one of Ebbinghaus' methods, is therefore a complement to the learning method. It permits a test of the power of the memory after different intervals of time.

Ebbinghaus found, according to this method, that forgetting proceeds at first very quickly and then more slowly.

The learning method and the saving method combined can be strongly recommended for pedagogical investigations.

7. Method of Reconstruction

The reconstruction method can only be briefly described. After the row has been read, the observer is given small slips of paper with the syllables printed on them, and is told to arrange the slips in the order in which the syllables appeared. The memory is here called upon to remember the order. The arrangement of the separate elements is used to measure the power of memory.

We shall close our chapter on memory by giving

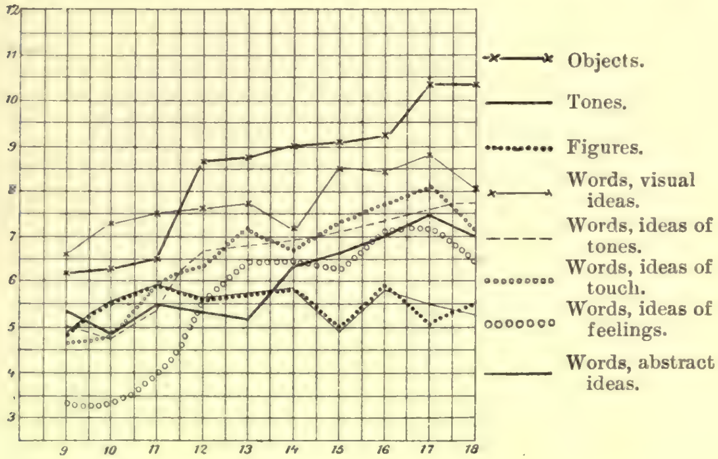


FIG. 223.—The memory of girls.

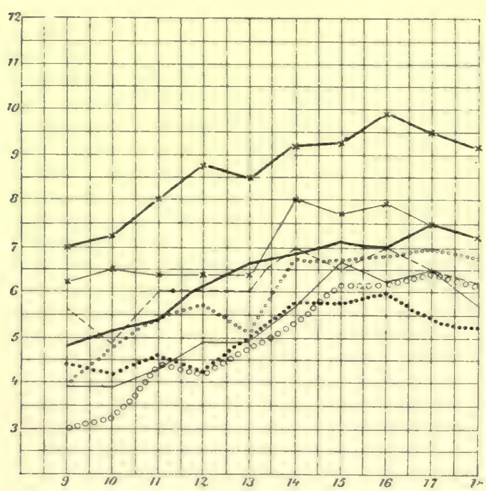


FIG. 224.—The memory of boys.

(From Netschajeff, *Zeitschrift für Psychologie*, 1900. Barth.)

the results for special memories, *i.e.* for objects, tones, &c., of Russian boys and girls (Figs. 223 and

224).[1] Besides different interesting details the following general phenomenon appears from the curves, that a decrease in the memory power appears with both boys and girls from 14 to 17. German boys, according to Pohlmann, also show their maximum at 14. Normal students from 15 to 20 do not reach this maximum.

The question, at what age the memory is best, is not

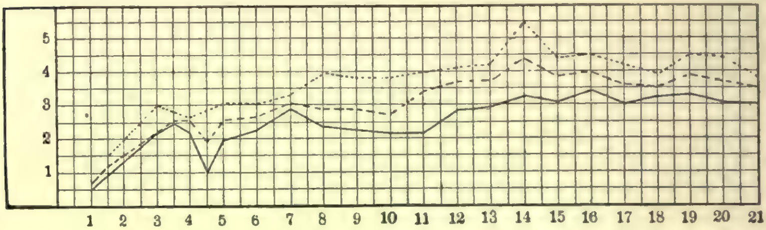


FIG. 225.—Boys.

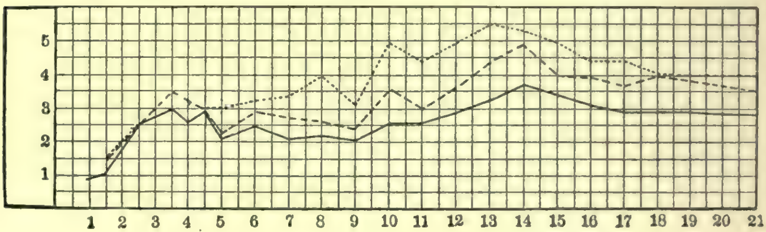


FIG. 226.—Girls.

FIGS. 225 and 226.—The first recollections at different ages of boys and girls.

(From Colgrave, *Memory, an Inductive Study*. New York, 1900.)

yet finally settled, since in the investigations the tests for immediate and prolonged retention were not always kept strictly apart. It is also of importance to investigate

[1] Netschajeff, *Experimentelle Untersuchungen über die Gedächtnisentwicklung bei Schulkindern*. Ebbinghaus' *Zeitschrift für Psychologie*, Bd. XXIV., 1900. Netschajeff showed the children twelve objects (newspaper, key, lamp, glass, &c.) and let them afterwards write down what they had remembered. In the second series they heard twelve noises (clinking of two glasses, rapping on the table, &c.), not seeing how they were produced. Then came words denoting (1) numbers, (2) visual objects, (3) noises, &c.

how the memory of the same children grows, by making tests at different ages.

An interesting fact in regard to this maximum of memory during the period of puberty is mentioned by Colegrave. He let his observers tell him their first, second, and third recollections of their lives, and he fixed as well as possible the years to which they referred. The earliest recollection of youths of 21 referred on an average to their third year (Fig. 225, the black line at age 21), the second recollection to the period between their third and fourth years (the curve of small strokes at 21). It is remarkable that at the age of 14 a turning-point seems to appear. At this age earliest recollections seem to be very weak; later they become much stronger. For example, the earliest recollection of fourteen-year-old girls refers to the age of $3\frac{3}{4}$, while that of seven-year-old girls to the age of 3 (Fig. 226). These results should be tested again.

We hope that by use of the experimental method we shall soon be able to obtain a comparative study of the development of memory at different ages, among different nations and races.

CHAPTER IX

APPERCEPTIVE COMBINATIONS

I. THE UNDERLYING PRINCIPLES OF THE METHODS OF INVESTIGATING THE COMBINATIONS OF THE APPERCEPTIVE PROCESS

MANY psychologists call every combination of elements of consciousness or of ideas, associations. This does not correspond to reality in so far as some of these combinations, the apperceptive combinations, differ essentially from the others, and this difference is that they possess a certain feeling of activity which is wanting in the other combinations.

If I give myself up to my thoughts or recollections, the elements of consciousness combine and dissolve apparently without any activity on my part. This same process of association occurs, when I give myself up passively to the impressions of the outer world. It is quite different, however, if I compare two things, if I look for points of similarity or of difference. In this apperceptive process I have a distinct feeling of activity, which accompanies this process.

With this we are advancing to still more complicated combinations. We are approaching the region of imagination and of thinking.

Wundt [1] has proved decisively that at these complicated psychological processes experimental investigation must make a halt, that we can only learn more as to the origin

[1] Wundt, W., *Über Ausfrageexperimente. Psychologische Studien*, Bd. III., 1907.

of these apperceptive combinations with the help of social psychology and comparative study of the origin of language.

For pedagogy, however, statistics as to the number of associations and apperceptive combinations that appear in a certain ideational process are of great value. Of course we gain nothing psychologically from these statistics. They tell us nothing as to the way in which apperceptive combinations arise. So far from giving any psychological help, the employment of the statistical method takes for granted that psychology already possesses a clear idea of apperceptive combination.

For pedagogy it is, of course, of the greatest importance to know in what degree apperceptive combinations and associations are present at each age in boys and girls.

We shall describe some of the methods that can be used to obtain such statistics.

II. TACHISTOSCOPIC EXPERIMENTS

Professor Külpe [1] carried out the following experiments with adults. He exposed visual objects in the tachistoscope. Each object was composed of four nonsense syllables. Each of these four syllables was printed in a diff rent colour. At each exposition the position and the colour of the syllables was changed. After each exposition new syllables were shown. The exposition time was $\frac{1}{8}$ sec. The observer had to look at the syllables and say what he had seen. This is just like the usual tachistoscopic experiments for measuring the scope of attention or of consciousness.

The next experiments were slightly different. The

[1] Külpe, O., *Versuche über Abstraktion. Bericht über den* 1, *Kongress für experimentelle Psychologie*, 1904.

observer was told to pay special attention to the colours of the syllables. This test showed that the colours were this time much better apperceived. This shows the process of abstraction. We are able voluntarily to pick out certain elements in a compound idea. We call this "abstraction."

If we carried out the same experiments with children, we could prove, by comparing our results with those obtained with adults, whether or in what degree children of different ages are capable of abstraction. If it were shown that certain elements, say colours, impressed the children so much that the instruction to pay special attention to the form made very little difference in the results, then we could say that children were capable of abstraction only in a small degree.

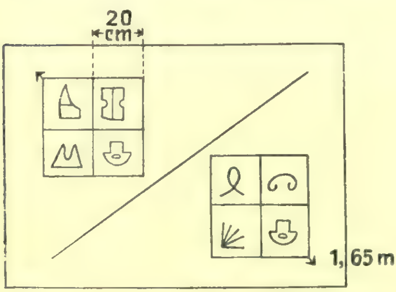


FIG. 227.—Visual object to test judgment of identity.

(From Grünbaum, *Archiv für die gesamte Psychologie*, XII. Engelmann.)

In a similar manner statistics of other apperceptive functions could be collected. We could show pictures in the tachistoscope, as in Fig. 227, and ask the observer to note whether two similar pictures are present. The number of right cases gives us a kind of measure as to the ease with which an observer can form judgments of similarity.

III. STATISTICS OF THE IDEATIONAL PROCESS

1. FREE REPRODUCTION

In the above-mentioned statistics of ideas we dealt only with the content of the ideas, here we are going to deal with the way in which they are combined.

(a) *Normal and Abnormal Ideational Processes.*

The normal ideational process of the adult, as is shown in his speech, is characterised by a preponderance of apperceptive combinations. As soon as pure associations obtain the upper hand, we conclude that his state of mind is abnormal.

What an ideational process without apperceptive combinations is, can be seen in the following speech of an insane person: [1] "If you would just come be—with the way—what now!—Oh, dear, dear! Oh, that is the whole closh—that's what! Oh, dear, dear me—an it is the other macock or macockiness—See! Who is what?—that—is it? Oh, age."

We note the so-called perseverations, the persistence of certain ideas, which always return, and the meaningless words. Really sensible connections seem to be absolutely wanting.

The drawings of such people are also similar, when the apperceptive activity is wanting. The patient who produced the picture in Fig. 228 wished to draw a horse with its rider. We see what has happened. He was not able to divide up the compound idea into its different parts and to put them together again in a drawing.[2]

If I tell such a patient to say the first word that occurs to him when I give him a word, a combination without any sensible connection will most probably result.

The copying of pictures can at times be carried out by certain insane people, when they are in the state of so-called "command-automatism," in which they imitate everything automatically. But even this can only be

[1] Wyllie, John, *The Disorders of Speech*, p. 206. Oliver & Boyd, 1894.

[2] Comparing this with the child's drawing in Fig. 198, we see how in that case a very difficult complex of ideas and relations has been excellently represented, if we do not take into account the mistakes in form.

FIG. 228.—Drawing by an insane person. "The first circle of ideas is a horse's body, with a rider, stirrup, spurs, &c. Only a part of the body and two legs had been drawn, when other ideas of animals or ghosts came between, and so instead of a horse's head we see a serpent's head, instead of a seated man, a ghost lying in the body of the horse, instead of spurs a mouse."

(From Mohr, *Journal für Psychologie und Neurologie*, VIII. Barth.)

done if the patient can apperceive the form with one grasp (Fig. 229). It is characteristic that the drawing is done at lightning speed.

In Fig. 230 we see quite a different picture. The

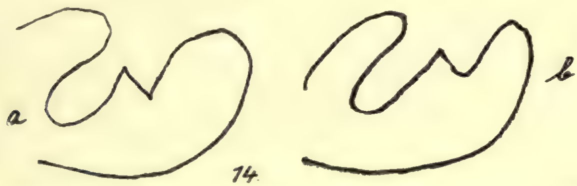


FIG. 229.—Drawing by an insane person in a state of command automatism. "Ordered to copy fig. *a*, he waved his pencil about in the air and then drew fig. *b*, with the most remarkable rapidity."

(From Mohr, as in Fig. 228.)

FIG. 230.—Drawing by an epileptic boy.

(From Mohr, as in Fig. 228.)

patient, not in the state of "command-automatism," is not able to copy the form (*a*) automatically. A normal person would be able to grasp this form easily by an apperceptive combination (similarity of the three curves). The epileptic does not possess this power. The first curve is in a kind of way achieved, but then other associations of movement appear, perhaps also uncontrollable ideas, and an incomprehensible scribble is the result.

(b) *The Methods of Investigation.*

The methods of investigation have been already suggested in our description of the ideational process of the insane.

A word is read out to the observer and he is asked to say or write down the next word that occurs to him. The method of allowing the observer to write down a whole row of words cannot be recommended. It makes a comparison of the results difficult. The ideas of each child, when once started, are sure to run on in a special direction.

It is also better, especially with older children and with children unknown to the experimenter, to make use of visual exposition, *e.g.* with the memory apparatus.

When we have carried out a large number of such experiments, we investigate the number of pure sound associations, of associations that fall under the categories of higher or lower concepts, of perseverations, &c. We can also note whether more general or individual ideas appear, and so on.

Let us mention a few results. Children use in their associations more ideas of objects, fewer of words, more individual than general ideas. More talented children are characterised by the possession of a vast number of individual ideas, not of general ideas or concepts.

With children of weak intelligence numerous perseverations appear. Meumann notes the case of a ten-year-old Swiss boy who associated "much" with "to lighten." All the verbs that followed received the same associations, *e.g.* "to work"—"to work much;" "to beat"—"to beat much," &c.

Also pure sound associations appear more often with such children, *e.g.* "to write"—"writes;" "to attend"—"attentive," &c.

The difference between an apperceptive combination and a pure association can be seen in the following examples :—

(1) "To lighten"—"a cooling down"; (2) "to lighten"—"much."

A comparison of the ideational combinations of children in dialect and in literary language would be interesting, *i.e.* of such children who speak in dialect out of school. We might see by such a comparison what influence the school exerts upon the richness, the method, and the rapidity (by measuring reproduction times) of the ideational process.

The method of collecting statistics of ideational combinations, which Groos [1] has made use of, deserves special mention. He showed adults and children sentences, *e.g.* "A bullet smashed the lamp," or "We started on our walk early in the morning." The observer was then told to ask a question, *e.g.* "Where did the bullet come from ?" or "Where did we go ?" These questions can then be arranged according to certain categories, *e.g.* dealing with spatial, temporal, causal, or other relations.

Groos found that questions as to the causal relations gradually increased in number from the age of 12 to 17 (from 32 per cent. to 53 per cent. of the total number of questions), that questions as to spatial relations were more in number and as to temporal relations less in number among children than among students.

We mention in conclusion, that along with this statistical method, the comparative study of the language and the drawings of children promises to give the best results for a psychological analysis of the ideational combinations of the child. A systematic investigation of the language of the school-child has up to now scarcely been

[1] Groos, K., *Experimentelle Beiträge zur Psychologie des Erkennens. Zeitschrift für Psychologie*, Bd. XXIX., 1902.

started. It has mostly been regarded from the point of view of its incorrectness.

The psychology of children's drawings has mainly busied itself with the purely formal problems of the arrangement of the picture on a plane surface. A great deal might be learnt as to the arrangement of a compound idea by giving the instruction, "Draw a living-room," &c.

2. Constrained Reproduction

The apperceptive side of the ideational process comes still more to the front, if we give special instructions during our reproduction experiments, *e.g.* to find the higher concept to the stimulus-word, *i.e.* the concept under which the word can be brought—branch—tree. The results of such experiments can be even more easily compared than those of the previous ones. The number of correct reactions gives us a direct measurement of the ease with which the particular combination can be carried out. In this way we can test systematically all kinds of apperceptive combinations. We can give as instructions the finding of a higher, a lower, or a similar concept. It is, of course, necessary to explain the instruction in simple language to the children and to carry out preliminary experiments with them.

It would be interesting to establish whether a broader or narrower style of putting the question gives the best results, and which of these styles has the advantage at each age.

IV. STATISTICS OF REPRODUCTION TIMES

If we can measure the reproduction times (of free and constrained reproduction), *i.e.* the time from the speaking of the stimulus word to the speaking of the reproduced

word, we obtain a new measure for the ease with which the different combinations, associations or apperceptive combinations, take place. Then we may take it for granted that in general the quicker the reproduction the easier it will be.

Such experiments have been carried out. They have shown that the reproduction times of children are much longer than those of adults. Adults require for free reproduction from $\frac{1}{2}$ to 1 sec., children from 5 to 10 secs.[1] According to Ziehen,[2] word associations follow quicker than object associations.

By practice the speed increases at first very rapidly, later very slowly.

In constrained reproduction the length of time is very much influenced by the difficulty or ease of the instruction. Watt [3] gave the following instructions :—

I. Find a higher concept.
II. Find a lower concept.
III. Find the whole to which this part belongs.
IV. Find a part of this whole.
V. Find a co-ordinate idea.
VI. Find a co-ordinate part.

Instructions II. and VI. required the longest times—1·5 to 1·8 secs. Instructions I., III., IV., and V. required 1·2 to 1·4 secs. They were, therefore, easier.

Watt also uses another method for measuring the time. He carries out a whole row of reproduction experiments successively with the intervals between each two constant. He calls out one word, and after four seconds the next, and so on. This interval is then shortened.

[1] Meumann's *Vorlesungen*.

[2] Ziehen, Th., *Die Ideenassoziation des Kindes*. Berlin, 1898.

[3] Watt, H., *Über Assoziationsreaktion. Zeitschrift für Psychologie*, Bd. XXXVI., 1904. *Beiträge zu einer Theorie des Denkens. Archiv für die gesamte Psychologie*, Bd. IV., 1905; also Bd. IX., 1907.

Watt experimented with intervals of 4, 3, 2, 1, and less than one second. The number of correct reproductions for each particular interval could then be established.

The shortening from 4 to 2 secs. made almost no change; in the first case there were 19 and in the second 17 correct reproductions. From $1\frac{1}{2}$ secs. downwards a great decrease was observed.

This method is much simpler than, but not as accurate as the first method.

V. METHOD OF TIME MEASUREMENT IN REPRODUCTION EXPERIMENTS

1. The Graphic Method

The measuring of reproduction times is in principle the same as that of reaction times (see p. 164 ff.).

We can therefore use here either the graphic or registration method.

Let us begin with the graphic, and with the case where the exposition of the stimulus word is visual. Two factors must be marked on the kymograph—the appearance of the stimulus word and the speaking of the reproduced word by the observer.

To expose the stimulus word we use the memory apparatus (Figs. 213, 214, and 217). On the pieces of paper (T, T_1, T_2, &c.) there are small pieces of silver-leaf (S), which pass over the two contacts (K*t*), seen in Figs. 214 and 215. These contacts are connected to a battery. The pieces of silver-leaf are arranged alternately more to the right and more to the left. At one piece of paper both contacts touch the silver-leaf, at the next only one touches, and so on. I arrange the apparatus so that only one contact is touching the paper that is exposed. On this paper there is a blank. The apparatus is then

set in motion, and the moment the first paper falls, the next paper with the stimulus word appears. At the same

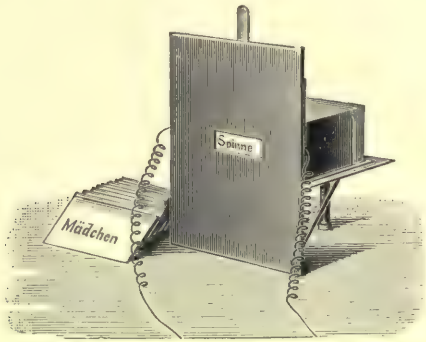


FIG. 231.—Alber's optical stimuli apparatus.

moment both contacts are touching the silver-leaf of this paper and the circuit is closed. Now if a recording magnet

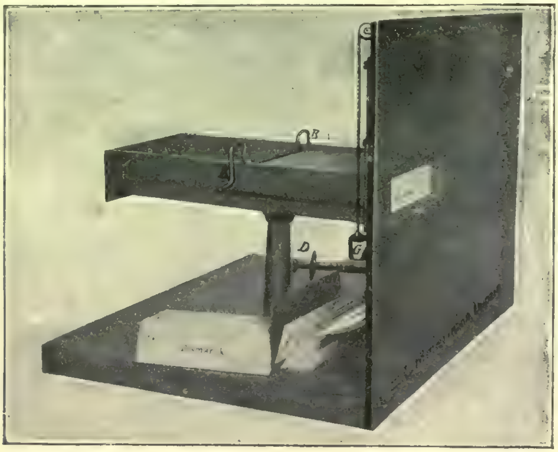


FIG. 232.—Minnemann's card changer.

is included in this circuit, the moment of the appearance of the stimulus word will be marked.

There are other instruments which effect the same thing, such as the apparatus of Alber (Fig. 231). A card

is pressed down by means of a lever and at the same time a contact is touched. Each time a new word appears the circuit is closed. A similar apparatus is that of Minnemann (Fig. 232).

We need, secondly, to mark the moment when the observer begins to call out the reproduced word. We must therefore have an apparatus which will break the circuit formed by the memory apparatus. This is accomplished by means of a voice-key (Fig. 233). The current from the memory apparatus goes to the screw *e*, through the thin steel rod *i*, to the metal point *d*, which is fastened on the round horn disc *c* with the nose *g*. This horn disc is extremely light and moves easily up and down (g, g_1). The nose *g* has the tendency to fall down, because of its own weight; it is, however, prevented by the steel spring *i*, and presses slightly against the steel plate *b*, which is fastened on the round mica plate *a*. The current therefore, so long as *d* touches *b*, goes through *b*, along the wire *k* to the screw *f*, and then to the recording magnet. The observer sits with the mica plate in front of his mouth. As soon as he speaks the reproduced word, the mica plate oscillates, *b* is disconnected

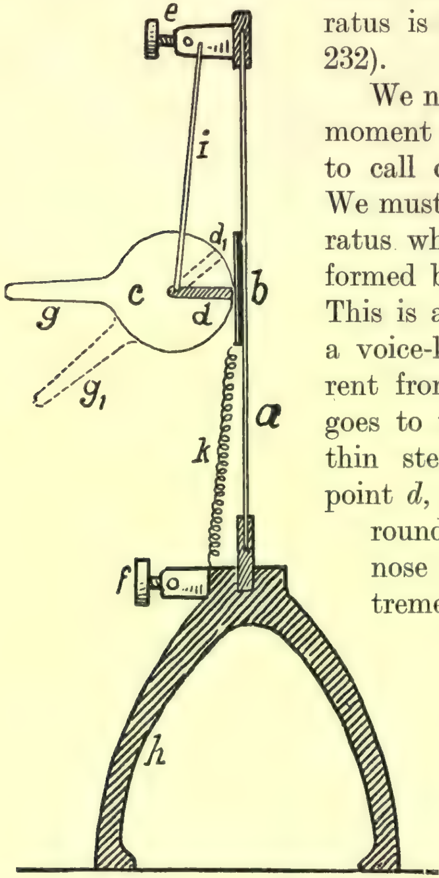


FIG. 233.—Diagram of Hempel's voice-key.

from c, the nose g falls down (g_1) and the metal point d goes upwards (d_1), and the contact is broken. The horn disc may touch b again, but the current cannot be conducted through it. The circuit is therefore broken as soon as the observer begins to speak (see also Fig. 234).

Fig. 235 shows the arrangement of the whole experiment. The current goes from the battery to the memory apparatus, then to the voice-key, then to the recording magnet and back to the battery. The apparatus may be,

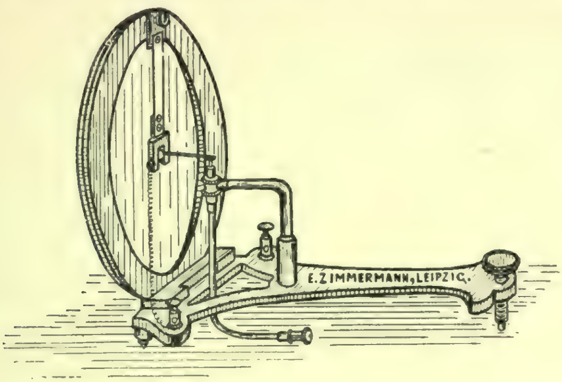


FIG. 234.—Hempel's voice-key.

of course, connected up in any other order. The Jaquet chronometer records the time under the recording magnet. (Our picture shows a tuning-fork instead of a chronometer.) The kymograph should be made to revolve as rapidly as possible, so that the fifths of a second may be each about 2 mm. long. Half millimetres can thus be fairly well judged, and they will represent a $\frac{1}{20}$ sec. Accuracy to a twentieth of a second is sufficient for reproduction times.

Each single experiment proceeds thus :—

1. Arrangement of the memory apparatus, so that a blank appears in the opening. Only one contact touches the silver-leaf.

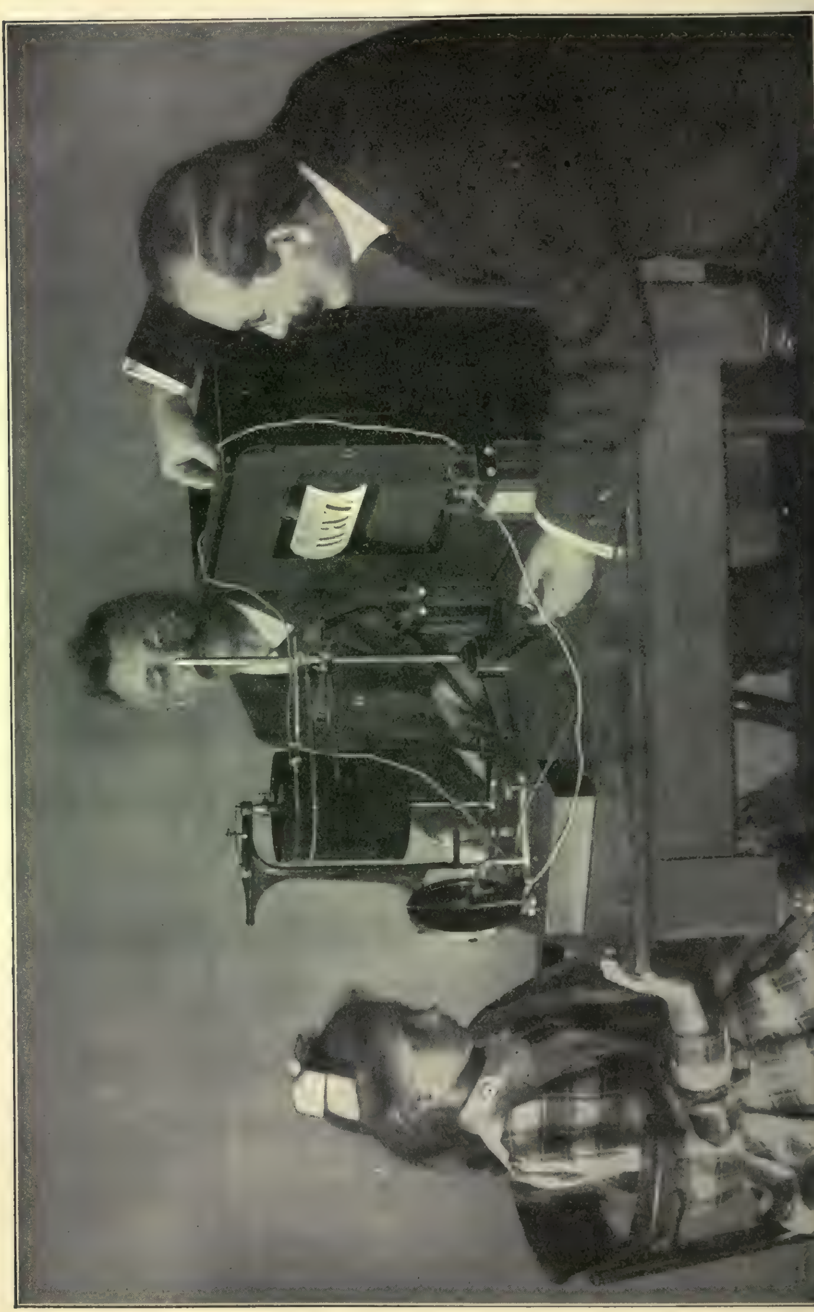


FIG. 235.—Arrangement of experiment for measuring reproduction times with the graphic method.

1. Recognition times.

FIG. 236.

Water—water.
·8 sec.

FIG. 237.

Oven—oven.
·9 sec.

FIG. 238.

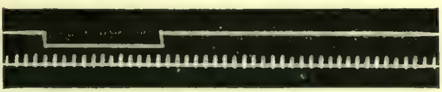
Evening—evening.
1 sec.

2. Free Reproduction.

FIG. 239.

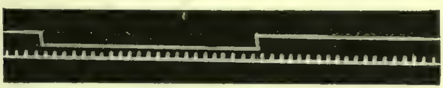
Key—cupboard.
2·1 secs.

FIG. 240.



Table—chair.
2·5 secs.

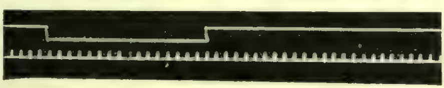
FIG. 241.



Rose—garden.
4·6 secs.

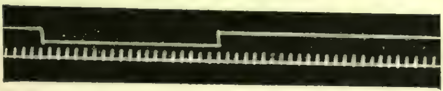
3. Constrained Reproduction. To find the part of the whole.

FIG. 242.



Tree—branch.
3·3 secs.

FIG. 243.



Horse—head.
4·0 secs.

FIG. 244.

Garden—flower.
4·5 secs.

4. Constrained Reproduction. To find the whole.

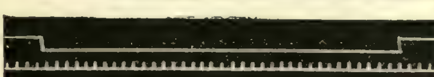
FIG. 245.

Roof—house.
4·2 secs.

FIG. 246.

Leg—body.
4·6 secs.

FIG. 247.



Back—chair.
7·3 secs.

Frida L., age 9.

2. Arrangement of the recording magnet so that it touches the smoked drum.
3. The setting of the chronometer in motion.
4. The placing of the nose of the voice-key in position.[1]
5. The setting of the kymograph in motion.
6. The setting of the memory apparatus in motion, and the giving of the signal, "Ready."
7. The stopping of the memory apparatus as soon as the first paper has fallen. We must do this at once, or else a new paper will fall after two seconds.

When the paper falls a word appears—"Apple." At the same time the recording magnet makes a mark.

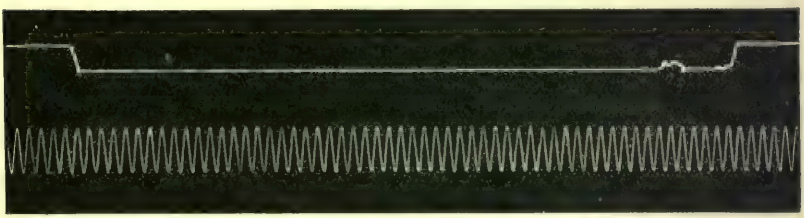


FIG. 248.—Perception time. "Apple"—"Yes." Graphic record with tuning-fork oscillations. (Frida L., age 9.)

After some time the observer says, "Pear." The circuit is broken, and the recording magnet makes a second mark.

8. The kymograph is stopped, and the experiment is finished.

Figs. 236 to 247 show the results of twelve such experiments that I carried out on a nine-year-old child. The recognition times were the shortest. The child had to read out the word aloud, as soon as it appeared. Free reproduction gives times from 2 to 5 secs. We see, from the

[1] This is best done by means of a pencil or something like it. Care must be taken that the nose does not go up too high. It must not lose its horizontal position.

constrained reproductions, that finding a whole for a part takes longer than finding a part of a whole.

If the times are very short, the spring kymograph and a tuning-fork can be used (Fig. 235) to mark the times. Fig. 248 shows such a curve.[1]

If one wishes to use an acoustical stimulus by calling

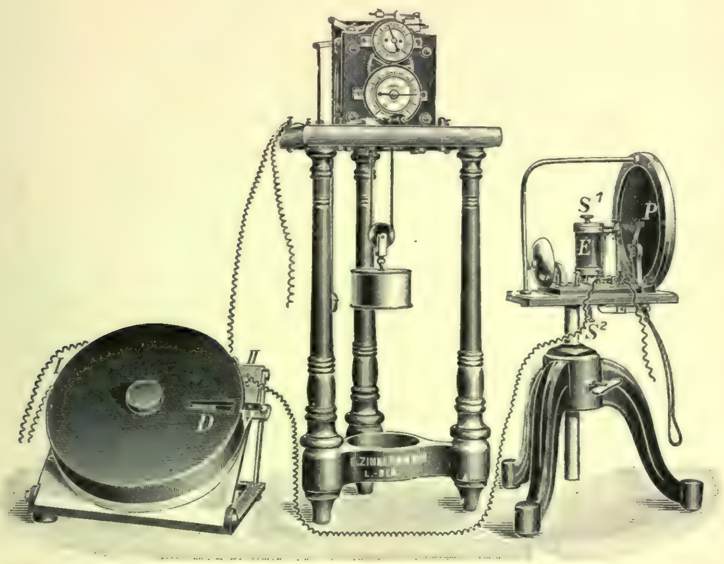


FIG. 249.—Measurement of reproduction times with Ranschburg's memory apparatus, chronoscope and voice-key.

out the stimulus word, the memory apparatus cannot be used. Instead we use a second voice-key, into which the experimenter speaks. On this voice-key the nose must be placed so high, that before the experiment begins there is no contact. When the experimenter speaks, the nose falls down to the horizontal position, where it is held by a small catch. This closes the circuit.

The voice-key is not so reliable in this arrangement

[1] The child was told to shout "yes" as soon as she noticed that there was anything on the paper. She was not required to read the word. The perception time was ·56 sec., as can be seen by counting the oscillations.

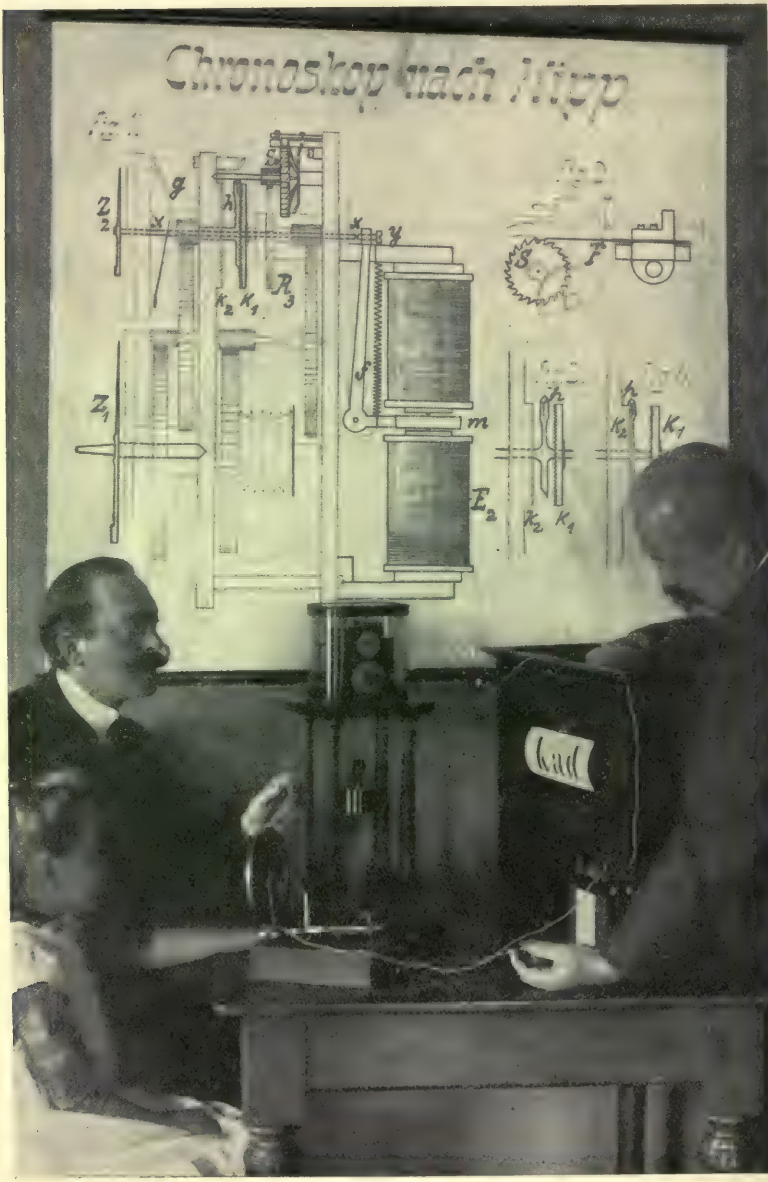


FIG. 250.—Measurement of reproduction times with memory apparatus, chronoscope and voice-key.

as in the other. We therefore recommend reproduction experiments with optical stimuli. If, however, we do wish to make experiments with acoustical stimuli, we must make use of a so-called commutator to help us. I must refer my readers to Wundt,[1] for the arrangement of the experiment in this case, which becomes slightly more complicated.

2. The Registration Method

With this method we make use of a chronoscope. instead of a kymograph and recording magnet.

Fig. 249 shows the arrangement of the experiment with Ranschburg's apparatus. Fig. 250 shows the arrangement with our memory apparatus.

In regard to the technicalities of the chronoscope we refer the reader to p. 177 *et seq.*

Lastly, we must mention that in all reaction and reproduction experiments the observer should be isolated, as far as possible. The chronoscope or any other noisy apparatus should be in another room, of course connected electrically with the other apparatus.

[1] Wundt, *Physiologische Psychologie*, 5 Auflage, Bd. III., p. 403.

CHAPTER X

SPEECH

I. ANALYSIS OF THE SOUNDS OF SPEECH

SINCE a psychological analysis of speech must principally depend upon the comparative method in social psychology, the room for experimental investigation is very limited.

FIG. 251.—Krueger and Wirth's larynx sound recorder.

Most success will be achieved by keeping to the most elementary phenomena.

For analysing the sounds of speech we possess an

excellent apparatus constructed by Professors Krueger and Wirth.

The larynx sound-recorder (Fig. 251) consists of a receiving-capsule, similar to the carotid capsule (Fig. 81, C). It is placed, not on the carotid, but on the thyroid cartilage, so that the oscillations of the cartilage, caused by speech, are transferred to the membrane of the receiver. The oscillations are carried to a writing apparatus, constructed on the principle of the Marey tambour (Fig. 82), only much more sensitive. Fig. 252 shows the writing apparatus. The rubber tube that comes from the receiving apparatus is drawn over the end of the short tube (to the right of the spiral spring). The upper end of this has an oval-shaped opening, over which a thin rubber membrane is stretched. In the middle of this is a small plate of aluminium *st*, which supports the writing-point *b*. It can be lengthened or shortened by means of the screw *m*. This point records the oscillations of the membrane on a band of paper that passes rapidly by.

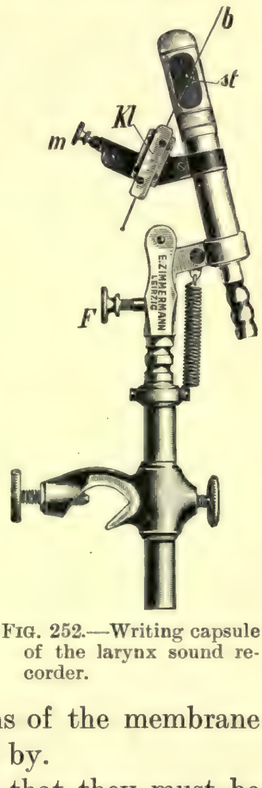


FIG. 252.—Writing capsule of the larynx sound recorder.

The curves produced are so small that they must be analysed by means of a magnifying-glass. They give us important knowledge as to the forms of oscillation of single consonants and vowels. They show, for example, that the *a* in the German word " Dach " is quite different from the *a* in " Sache," since the preparation for the following *e* slightly changes the *a* in " Sache." In fact every preceding or following sound exerts its influence

both ways. Such investigations may become important for the theory of teaching reading, and for investigating defects of speech in children.

II. ANALYSIS OF THE MELODY OF SPEECH

If a piece of paper is passed over an open flame, regular streaks of soot are formed. If we speak or sing on to the flame, we notice how it trembles. It follows the oscilla-

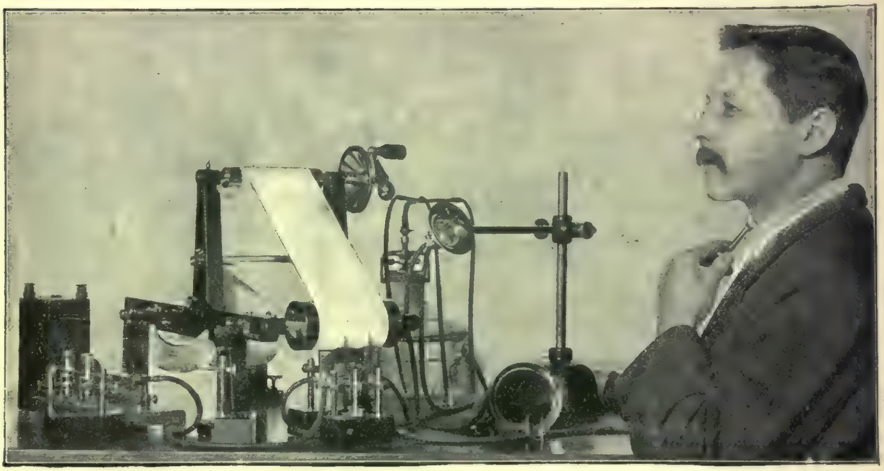


Fig. 253.—Marbe's apparatus for the melody of speech.

tions of the sound, and it becomes intermittently larger and smaller. With a long flame of gas this flickering is seen very clearly. Now if I pass a piece of paper through such a flickering flame, I do not get regular streaks of soot, but a chain of soot rings. Each oscillation of the flame causes a new ring. By this simple method the number of oscillations of a spoken tone can be recorded. If I speak in a high pitch, the soot rings draw close together; if I let my voice fall, the rings spread out.

On this simple principle Professor Marbe founded his method of smoking flames to record the melody of speech,

and demonstrated it in 1908 at the Psychological Congress at Frankfurt.

Fig. 254 shows a demonstration apparatus for schools. It must be connected with an acetylene apparatus that feeds the flame. The rubber tube at the left goes to the gas-burner. It ends in a capsule with a rubber membrane, just like the carotid capsule. We can either speak directly into the flame or into the tube against the rubber membrane. In both cases we obtain rings of soot. I may also hold a capsule against my thyroid cartilage, as in Fig. 253.

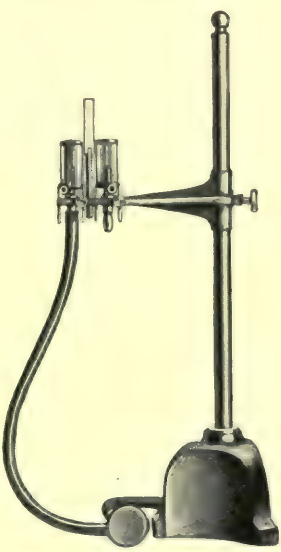


FIG. 254.—Demonstration apparatus for schools.

If I hold a vibrating tuning-fork near the flame, the oscillations will appear as rings of soot at equal distances. Similarly, if I press my finger on the membrane one ring will be formed.

Fig. 253 shows the whole of Marbe's apparatus.[1] A very long strip of paper (400 metres) passes over three flames. The first flame records the speech, the second the oscillations (100 per sec.) of a tuning-fork to mark the time, and the third is connected with a contact-key which can be pressed down to cause one soot ring at certain times, say at a certain raising of the voice.

These marks facilitate the analysis of the rings. Between the flames are thin vertical pieces of tin to prevent the oscillations of one flame from being transferred to another.

[1] Both these instruments can be obtained from Joos, the mechanician of the Psychological Institute at Frankfurt on the Main.

After fixing the soot rings, they can be analysed. Their distance from each other allows us to fix accurately the pitch of the voice, and tells us how far it is subject to fluctuations, and whether change in pitch goes along with change in accentuation.

An investigation of the melody of speech of the deaf and dumb would be interesting. We might find in their monotone some differences in pitch, upon which we could build with the hope of arriving at some melody of speech in the future.

Further, the differences in the melody of speech of children of different ages might afford help in the development of the speech of the child during his school years.

III. STATISTICS OF THE FORMS AND COMBINATIONS OF WORDS

We only possess detailed statistics of the language of the child for the early years of its life. Ament [1] collected the first two hundred ideas of his children, and arranged them according to the forms of speech. He also investigated how the concept of certain words changed in the course of development, became smaller or larger.

Similar investigations could be made with older children. It would be specially interesting to determine the store of words of the normal six-year-old child. This could only be done by some one who was always in the child's company. For a certain time all the words that the child used would have to be noted. The task would, of course, be enormous, but it is not an impossible one, and would certainly be a thankful one.

In the higher classes a comparative investigation of

[1] Ament, W., *Entwicklung von Sprechen und Denken beim Kinde.* Leipzig, 1899.

the written and spoken language of children would be interesting.

We can also, by means of reproduction experiments with measurements of reproduction times, arrange such material according to the ease of combination. Menzerath [1] has proved that the most familiar word combinations give the shortest reproduction times. He picked out the reproductions, where all his eight observers associated the same word, and assumes these to be the most familiar word combinations. These gave the shortest reproduction times. The middle value for the unfamiliar combinations was 1400σ or 1·4 sec. This value appeared with 50 reproductions. The middle value for the familiar combinations was 1150σ, which appeared 65 times. Only the pure sound associations were shorter, about 1000σ.

We have, therefore, in the reproduction times a measure for the familiarity of the combinations in question. To determine which combinations—noun with adjective, noun with verb, &c.—are most familiar to the child, it is not necessary to gather statistics of all word combinations that appear. It is sufficient to carry out a number of reproduction experiments with material varying as much as possible, and to measure the reproduction times.

From the length of the reproduction times for the combination, noun-adjective, we draw conclusions as to the familiarity of this combination at the age in question.

A comparison of the reproduction times when using dialect with those when using the literary language has not yet been made.

Especially in investigating the pedagogical influence, say, of grammar, on the familiarity of certain combinations, experiments in the dialect or conversational language

[1] Menzerath, P., *Die Bedeutung der sprachlichen Geläufigkeit, &c. Zeitschrift für Psychologie*, Bd. XLVIII., 1908.

of the child should always be made for purposes of comparison, in order to determine what influence the teaching of grammar really has on the speech of the child, and whether we are not only developing a school language by the side of the natural mother-tongue. If the reproduction times in dialect show an essentially different tendency in regard to the distribution of the familiarity of ideational combinations, and if the changes in the reproduction times of certain combinations brought about by school-teaching are not transferred to the dialect, then the value of our teaching of grammar as a means of developing the child's speech cannot be reckoned very high.

IV. SPEECH AS A MEANS OF EXPRESSION

Two points in regard to the development of language must not be forgotten. First, that speech is only one of many ways of expression, and that it has developed out of the movements of the whole body. The little child moves hands and feet to show his joy, and he knows, even before he can speak, how to make himself understood to his mother by means of all kinds of bodily movements. Later a shout of joy is joined to these movements, and then out of these first exclamations speech slowly develops, always accompanied with the vivacious bodily movements that were used at first. Even in later years (Fig. 255) he likes to use the whole body as a means of expression in his play. About this period the child is sent to school.

It is quite a natural process, that as intellect develops speech becomes more and more the means of expression. It proves itself to be the most sensitive instrument for expressing our ideas. This development must not be retarded.

But it is absolutely wrong suddenly to demand of the

six-year-old child to "keep quiet" when speaking. For him the mimic and pantomimic movements are still an essential means of expression. He makes no serious speech without vivacious movements accompanying it. If we try to stop this suddenly, we are hindering his natural development. The little child, who up to now found a joy in speech, becomes dumb.

Secondly, we must remember that development of speech originates in the expression of feeling. Therefore

FIG. 255.—The body as a means of expression in the games of children.

(From Pabst, *Neue Bahnen*, 1905. Voigtländer.)

mimicry and pantomime remain an essential part in the expression of our feelings, not only when young but during our whole life. A happy man with his head hanging down is just as impossible as a sad one gesticulating joyously with his hands.

If then speech is to give a true expression of our feelings, we should not suppress mimic or pantomimic expression even in the higher classes. Even the suppression of pantomimic movements seems to have an unfavourable influence on mimicry. If we do suppress such

Fig. 256.

Lovely was the evening,
Silver clouds flew by
Over all the spring landscape
Joyous in the sky.

Fig. 257.

On the side of yon steep hill
Were graves, where dead men lie,
And on the wall the Cross stood there
In silent grief *on high.*

Fig. 258.

The post-boy heeded not, *but cracked*
His whip with all his will,
And let his horn ring merrily
Over dale and hill.

Fig. 259.

On we drove with jangling noise
Past field and wood and rill,
But long there sounded in my ears
The tone from yon steep hill.

Figs. 256–259.—Recitation without gesture.

movements, we cannot expect that in the recitation of a poem proper expression should be given to the feelings it is meant to awaken.

To prove the disturbing influence of the suppression of pantomimic movements on the mimicry of the face, I carried out the following experiment.

I made a class recite a poem, Lenau's "Post-boy,"

FIG. 260.—Poem as in Fig. 256. "Joyous in the sky."

Observer A. "The expressions show joy. They seem to say, 'How fresh and lovely the morning is. Lovely, wide and free?" Observer C. "The children are in an excited joyous mood. Two look bold, almost fool-hardy. I think it must be some poem of nature, something like 'the spring has come'"

as they were accustomed to do. As they were reciting I took photographs at various striking passages (Figs. 256 to 259). I showed these pictures to a number of adults and asked them to describe the feelings of the children. Most of these observers said that the faces of the children were so expressionless that they could draw absolutely no conclusions. None of the observers were able to decide to which lines of the poem the particular pictures belonged.

FIG. 261.—Poem as in Fig. 257. "In silent grief on high."

Observer A. "The mind seems to see something great that rises up in front of it, great and wonderful, but not with joy, rather with reverence. Something great seems to be affecting them and they have quite forgotten that they are being photographed. They are saying something like this, 'It stood high and mighty, towering over all the land.'"

FIG. 262.—Poem as in Fig. 258. "But cracked his whip with all his will."

Observer A. "The picture shows a feeling of power. The eyes light up. Expressions of joy. They seem to be saying, 'I am a hero.'"

I now photographed other children who were accustomed to make use of pantomimic movements as much as they liked in order to give expression to their feelings (Figs. 260 to 263). The observers could now

FIG. 263.—Poem as in Fig. 259. "The tone from yon steep hill."

Observer A. "They hear something that is approaching. Something that troubles the soul, because it is doubtful, unclear." Observer B. "It is something serious, frightening. They do not know exactly what it is." Observer C. "Obvious expressions of listening. It is not the call of a bird nor is it a song. They seem too reverent for that. This seems to point to the tones of a bell. The eyes are turned upwards. This seems to point to the fact that the tones come from above or from a distance."

easily guess, out of the children's expressions, the feeling-tone of the poem, as the text at the bottom of the pictures shows.[1] When the poem was also shown, most of them found the lines to which the pictures corresponded.

[1] Of course only the faces of the children must be shown, if it is desired to prove my contention that pantomimic movements help facial expression.

CHAPTER XI

PHYSICAL WORK

WHOEVER expects the school to exert an educational influence besides the mere cultivation of the intellect, will certainly expect a training in manual work to be included in the curriculum. The necessity at the present time of emphasising this point is drastically proved by the fact that most educational text-books only treat manual training as a secondary subject, if they treat it at all. We cannot here discuss the question as to whether the curriculum of our schools should be radically altered in order to give physical work its due. In gymnastics, writing, &c., the body plays a large part, in fact there is no kind of mental work where the body has not its share of work.

For these reasons it is necessary to seek a measure for the capacity for bodily work, and to study thoroughly the laws governing bodily work in children and in adults.

I. THE ERGOGRAPH

1. Ergographs with Weights

The organs, by means of which the human body accomplishes physical work, are in the main the muscles. The laws of muscular contraction, therefore, form the basis of a theory of work. Physiology has accurately investigated the work of the dead muscle. Pedagogy is, of course, only interested in the capacity of the living muscle, and above all in the process of voluntary contraction.

The methods in this case can obviously never be as exact as those of physiology, which deal with the single muscle separated from the body, and therefore isolated from all other influences, except the influence of the stimulus which is to be investigated.

We have to thank Mosso for the first ergograph, or force-recorder (Fig. 264). The arm, the first and third fingers are fastened down tightly. The middle finger, fastened in a little cap, is free to move. If the finger is bent,

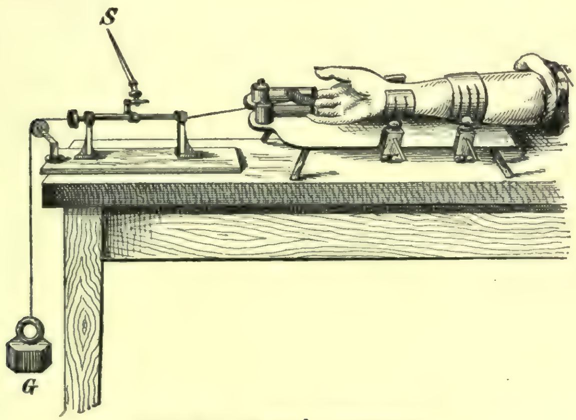


FIG. 264.—Mosso's ergograph.

the cord is pulled upward and the weight is raised. To the cord a writing-point is attached, which moves up and down as the finger is bent or stretched. The length of this movement corresponds exactly to the distance the weight is lifted. If the weight is 6 kg., the distance 5 cm., the work accomplished by one lift is ·3 kilogrammetres. If I can carry out ten such lifts in ten seconds, my work amounts to 3 kilogrammetres.

I put near the writing-point a kymograph that revolves slowly. The separate lifts are recorded. I measure them, multiply by the weight lifted, and so obtain the capacity of the muscle in kilogrammetres.

The Mosso ergograph has been often improved upon since its first construction, in regard to the fastening of the arm in order to prevent other muscles from moving

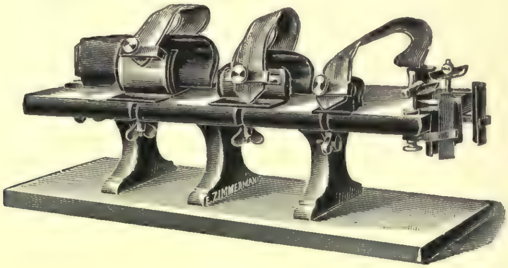


FIG. 265.—Arm-rest for ergograph.

(Fig. 265), and also in regard to the registration of the lifts. The recorder in Fig. 266 shows a practical arrangement, which according to my knowledge was invented by Professor Meumann. A measuring tape is stretched

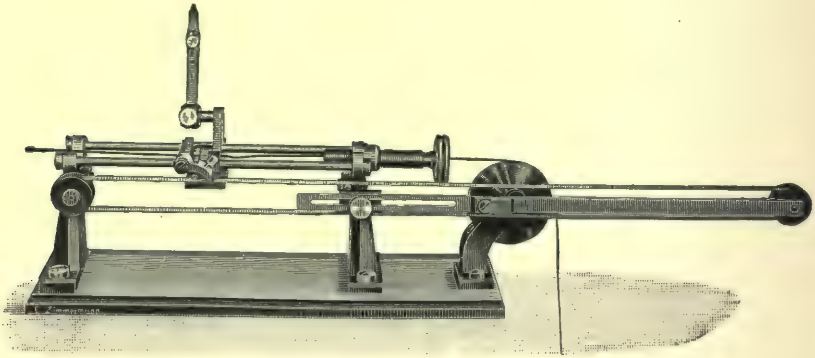


FIG. 266.—Recording arrangement of an ergograph with an endless measuring tape.

over two small rollers. When the weight is lifted, the little sharp catch attached to the recorder slides over the tape without moving it; when, however, the recorder moves backwards, the catch pushes the tape along with it. This occurs after every lift. If the child has accom-

plished twenty lifts, the tape has moved twenty times along, say from 0 cm. to 60 cm. If the weight was 8 kg., he has therefore accomplished 1·8 kilogrammetre. This is a simple method when we only wish to measure the total work accomplished. Meumann's ergograph for children (Fig. 267) is provided with a similar recording apparatus.

Fig. 268 shows Trèves' ergograph for testing the power of the muscles of the arm. The kymograph records a curve in the usual way. The muscles of the arm or leg

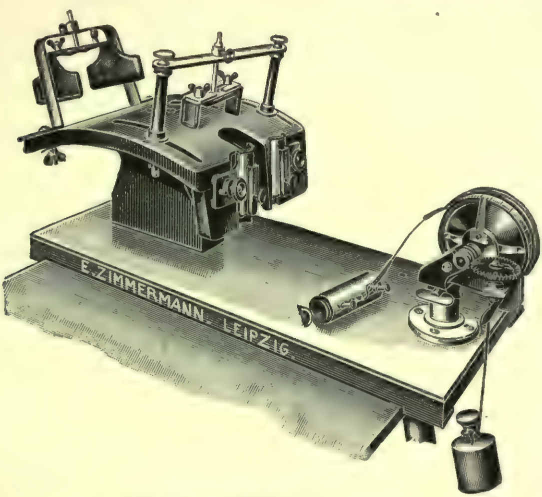


Fig. 267.—Meumann's ergograph.

can be tested just as well as those of the finger. Even the capacity of all the muscles of the body may be tested. Such problems are of less importance to pedagogy, and the ergographs for such special problems cannot be described here.

Pedagogy is mainly interested in two questions. Firstly, the form of progress of bodily work. I can study this on any special muscle, since physiology tells me that the laws of work for the different muscles are essentially the same.

Secondly, pedagogy is interested in individual differences and in the possibility of influencing work by different conditions. These problems may also be studied on any particular muscle. Therefore it is best in pedagogical

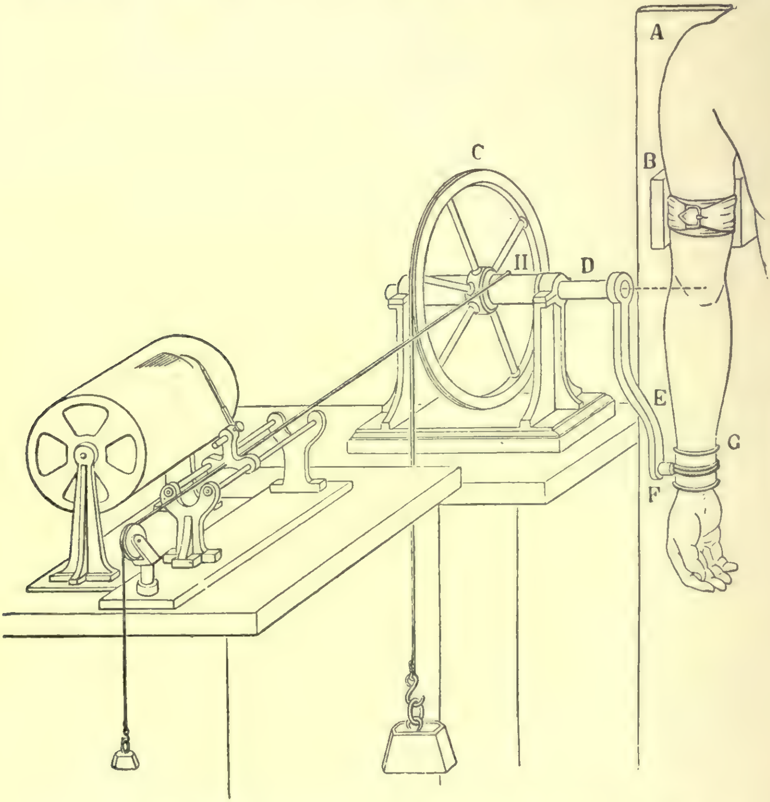


FIG. 268.—Ergograph for investigating the working power of the biceps. (From Trèves, *L'Année psychologique*, 1906.)

investigations to limit oneself to the simpler apparatus, which test the muscle of the finger.

The apparatus we have described have all been so constructed as to fasten the arm as tightly as possible in order that only one muscle may be moved. It has been proved, however, to be impossible absolutely to isolate

one muscle of the living being. Even if the arm is tied down as tightly and as well as possible, not only one group but several groups of muscles always are at work. It is

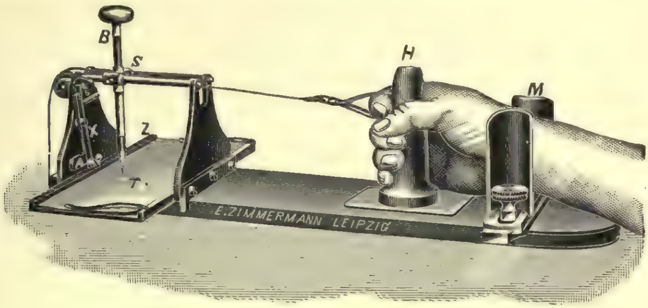


FIG. 269.—Dubois' ergograph.

best, therefore, not to attempt the impossible by fastening down the arm, but to allow a comfortable and natural position.

For this reason I recommend for pedagogical investigations Dubois' ergograph (Fig. 269). The hand grasps

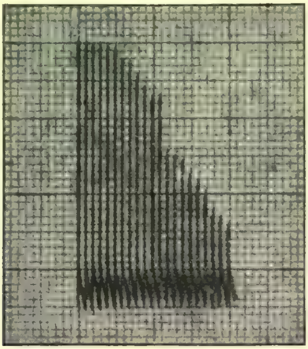


FIG. 270.—Ergogramm on millimeter paper.

tightly a wooden handle, H, which can be screwed backwards and forwards. Only the wrist is held tightly between the metal clamps M. The recording apparatus is extremely simple. It consists of a pencil, B, which moves backwards and forwards with the movements of

FIG. 271.—Demonstration of an ergograph curve on the kymograph.

the weight and draws a record on the paper placed below. If this paper were stationary the marks would be drawn all upon the same place. To prevent this there is an arrangement by which the moving back of the pencil, by means of the clamp A and the rack Z, moves the paper one millimetre along, so that each movement is recorded a millimetre apart. If squared millimetre paper is used, the height of each movement can be easily calculated.

Fig. 270 shows such an ergogramm (ergograph curve).

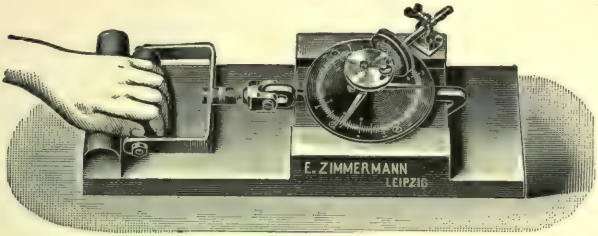


Fig. 272.—Lehmann's ergograph.

For adults a weight of 5 to 8 kg., for children a weight of 2 to 6 kg. should be used.

For demonstration purposes a recorder as in Fig. 271 can be used, so that the records can be seen from a great distance.

2. Ergographs with Springs

After I have worked with a weight of 8 kg., so that I am not able to raise it even a millimetre high, it would seem as if the muscle were absolutely exhausted. If the weight is suddenly lightened to 1 kg., I can, however, go on lifting it with ease. An ergograph with weights does not therefore measure the total capacity of the muscle. Certain French psychologists use a spring instead of a weight. At first it can be stretched with little exertion, but the larger the movement becomes, the more strength is required.

Fig. 272 shows a similar apparatus constructed by

Professor Lehmann of Copenhagen. The stretching of the spring is recorded on a scale.

The new ergograph of Professor Henry of Paris

FIG. 273.—Professor Henry's ergograph.

(From *Die Umschau*, 1908.)

(Fig. 273) consists of a rubber ball filled with mercury which is pressed with the fingers. The mercury rises up in the long tube, and therefore the pressure of the mercury in the tube becomes greater the more the ball is pressed.[1] On the mercury a piece of iron swims, going up and down with the mercury. A tube connected with this transfers the movements on to a kymograph.

A criticism of spring ergographs and similar apparatus would lead us into a physiological discussion, which cannot be entered on here. I agree with Trèves,[2] who does not recommend the spring ergograph.

II. THE MEASUREMENT OF PHYSICAL ABILITY

1. Ergograph Curves

The normal curve obtained with a weight ergograph looks like the one on Fig. 274, showing a gradual fall. The weight was $4\frac{1}{2}$ kg., and each lift followed after a pause of $\frac{3}{4}$ sec.

Curves like the one in Fig. 275 generally mean that a certain amount of practice has taken place during the experiment. Those like the one in Fig. 276 point to a fair degree of fatigue.

If one is fatigued by some previous work, this fatigue shows itself in the small number of pulls accomplished

[1] von Stein, "Nouveau dynamométrographe universel et ergograph et leur importance pour le diagnostic des désordres du labyrinthe de l'oreille" (*Le physiologiste Russe*, Moscow, 1906), gives a description of a weight ergograph where the weight hangs down over a lever that turns on an axle. If I turn the axle (by pulling with the finger) the weight will at first be raised only a little. The more the lever with the weight approaches the horizontal position, the more force it exerts. Here again the force necessary at the beginning is very small, and becomes steadily greater as I continue pulling.

[2] Z. Trèves, "Über den gegenwärtigen Stand unserer Kenntnis die Ergographie betreffend," *Pflüger's Archiv*, Bd. 88, 1901 ; and "Le travail, la fatigue et l'effort," *L'année psychologique*, 1906.

and also in the fact that the maximum is reached after a certain number of pulls have been made (Fig. 277).

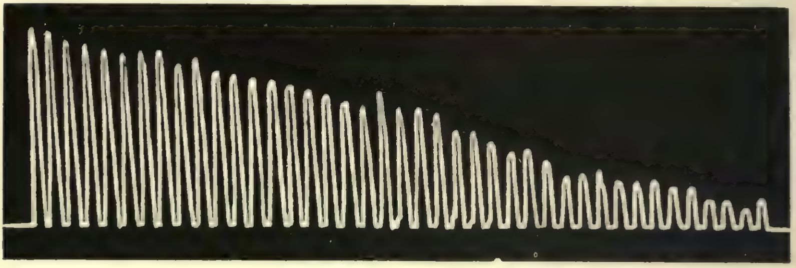


FIG. 274.—Normal ergograph curve.

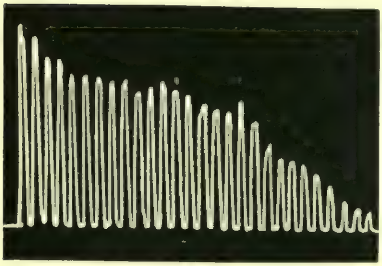


FIG. 275.—Practice curve.

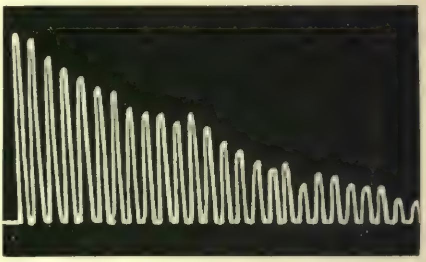


FIG. 276.—Fatigue curve.

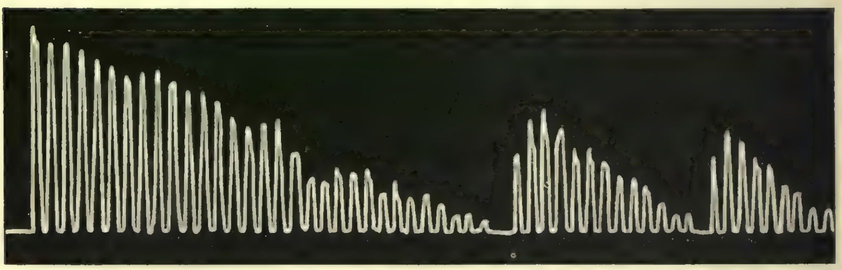


FIG. 277.—Fatigue curve with short intervals of rest.

The physical ability after doing a piece of mental work (Fig. 279) showed itself to be greater than before (Fig. 278). This, of course, depends upon the length of time spent on the mental work. If this is short, it tends

to stimulate; if it is long and fatiguing, it has the opposite effect.

2. The Maximum Ability

I let one observer work with $4\frac{1}{2}$ kg. until exhausted, *i.e.* until he was unable to pull the weight up again. I then took away 3 kg., so that only $1\frac{1}{2}$ kg. remained

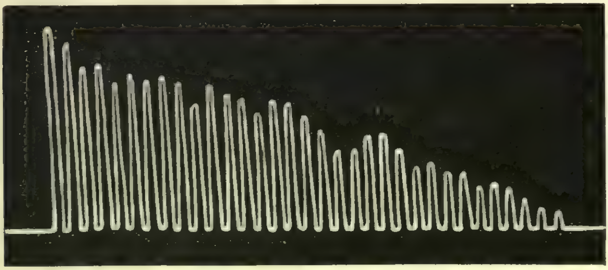


Fig. 278.—Muscle power before learning by heart.

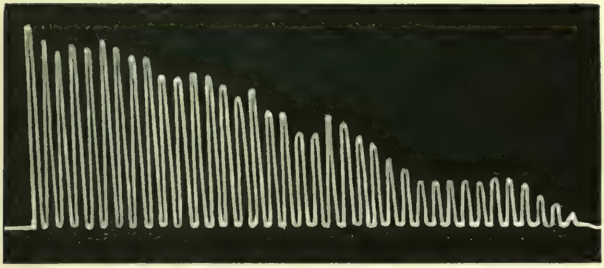


Fig. 279.—Muscle power after learning by heart.

(Fig. 280). The muscle was immediately capable of carrying out a fair amount of work. It is therefore not correct to say that the muscle is absolutely exhausted, if it cannot lift $4\frac{1}{2}$ kg. any more. We cannot, therefore, test the maximum ability of the muscle with a weight of $4\frac{1}{2}$ kg.

It might be said that we should therefore use a smaller weight, say $1\frac{1}{2}$ kg. The result is shown in Fig. 281, in the so-called infinite curve. The observer never stops pulling. We have not obtained the maximum ability

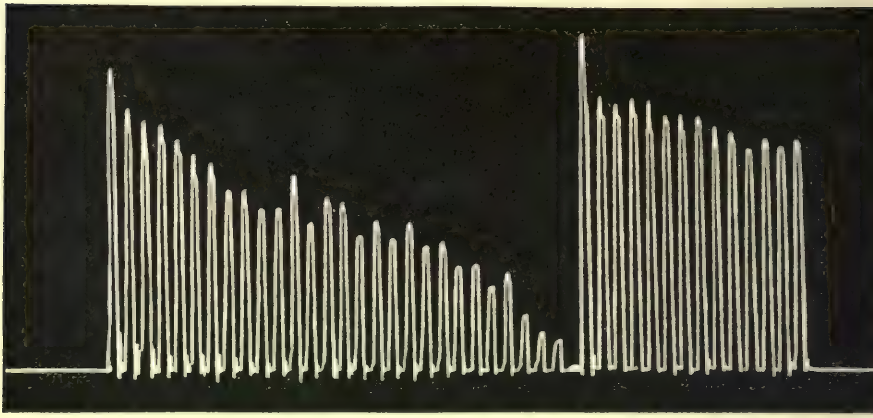


FIG. 280.—Lifting $4\frac{1}{2}$ kg. till exhaustion, then continuing with $1\frac{1}{2}$ kg.

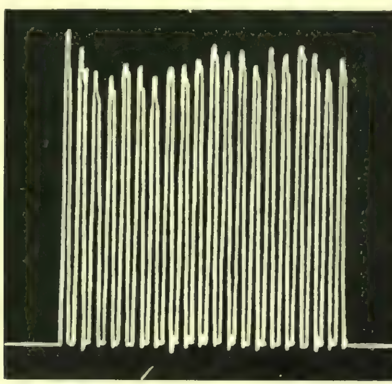


FIG. 281.—"Infinite" curve. Weight, $1\frac{1}{2}$ kg.

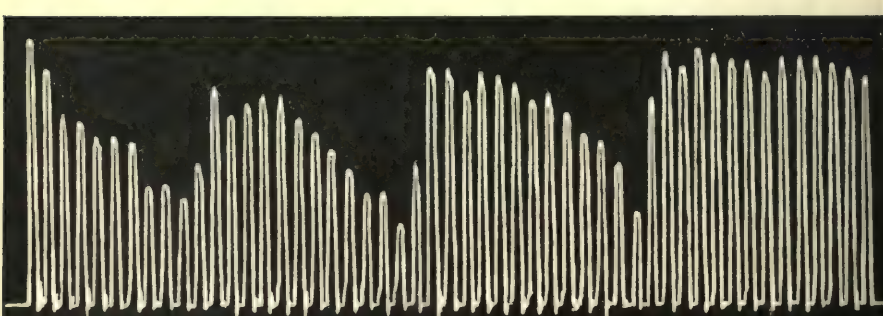


FIG. 282.—Continuous work on the ergograph with gradual decrease of the weight according to Trèves' method. At first $4\frac{1}{2}$ kg., then $3\frac{1}{2}$, then $2\frac{1}{2}$, and at last $1\frac{1}{2}$ kg.

here, for the observer could pull a much greater weight.

Trèves discovered a very ingenious method. We begin with a heavy weight, but as soon as we note that the curve begins to sink, we take a little off. And so we continue until the curve ceases to sink, until the infinite curve begins to make its appearance. Fig. 282 shows such a curve; $4\frac{1}{2}$ kg. were used at the beginning, and 1 kg. was taken away at a time until at $1\frac{1}{2}$ the infinite curve appeared. We thus really obtain the maximum ability of the muscle, which can be directly represented by the amount of the weight that can be continuously lifted at a definite rhythm. The great importance of Trèves' method is that it approaches so nearly to the conditions of work in everyday life.

It is the same whether the purpose of the work of our muscles is to move our body from one place to another, to lift or to carry weights, or to move pen or pencil—in all these cases it is the case of exerting a certain regular force at certain intervals. I do not judge the physical ability of a porter by the fact that he can carry a hundredweight for two seconds, but I test whether he can carry an average weight without over-exertion for hours.

If I wish to investigate a state of fatigue by using Trèves' method, I must put my question thus: "What is the heaviest weight that can be continuously lifted in a state of fatigue, *e.g.* after five hours of school?" In testing individual differences, it is sufficient to give the maximum weight that can be continuously lifted.

If it happens in using Trèves' method that a regular curve is never achieved, then we are dealing with abnormal or ill people or with sham patients (lazy ones). Such curves show particular characteristics. One of these is their abrupt cessation. The hysterical patient (Fig. 283) begins (at the right) with a fair production and

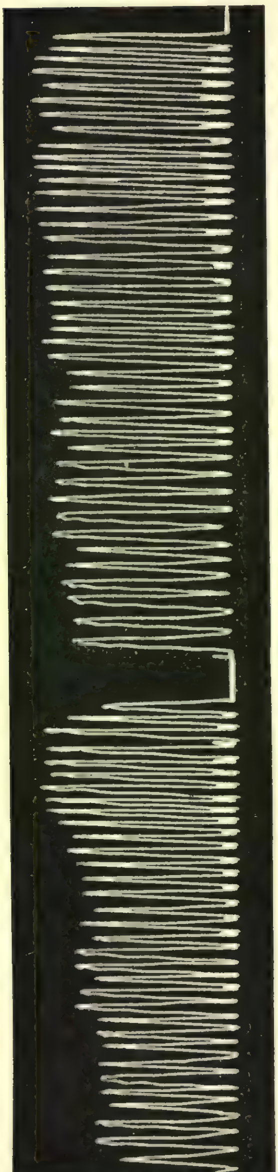


FIG. 283.—Ergograph curve of a hysterical patient. To be read from right to left. In the middle there is an interval of two minutes.

(From Breukink, *Journal für Psychologie und Neurologie*, Bd. 4, 1904. Barth.)

FIG. 284.—Ergograph curve of a patient suffering from chorea. To be read from right to left. In the middle there is a pause of two minutes.

(From Breukink, as in Fig. 283.)

works quite evenly. Suddenly she cannot pull any more. "No, it is absolutely impossible." After a very

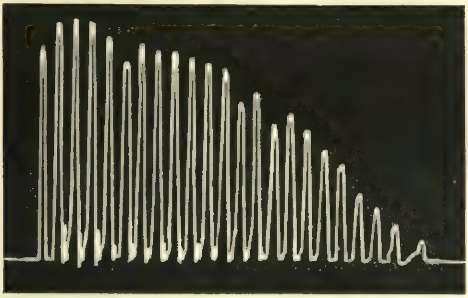


FIG. 285.—Normal curve. Pulling with all his might.

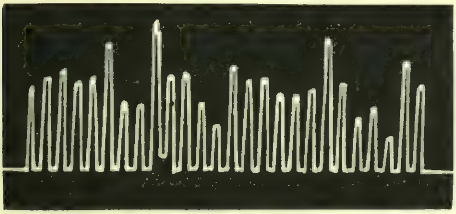


FIG. 286.—Curve of a sham patient. Pulling with half his might.

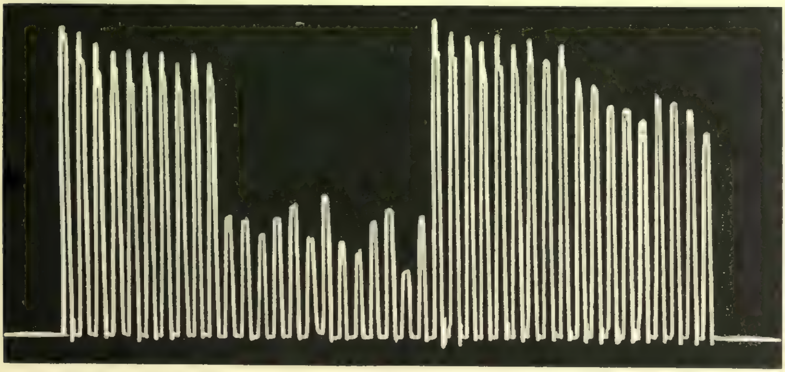


FIG. 287.—Normal and sham curves. At first with all, then with half and at last with all his might.

short pause, however, she continues admirably. Such a sudden cessation never occurs with healthy people. The case of St. Vitus' dance shows the characteristics

of the illness in the great irregularities of the curve (Fig. 284).

Fig. 286 shows the curve of a sham patient. The observer was quite accustomed to ergographic experiments, but he was told to work only with half his might, and to take care to make the curve regular. We see the difference by comparison with the normal curve (Fig. 285). Fig. 287 shows the same observer first working with all his might, then with half, and then again with all his might. Here again we see the regular falling-off of the curve when working with all his might, and the irregular curve when working only with half his might.

Laziness, as well as certain nervous disorders, can be easily discovered by means of the ergograph.

III. RHYTHM AND WORK

Awramoff[1] started out to investigate what could be accomplished on the ergograph when working with and without rhythm. He made the remarkable discovery that there was no single observer who did not after two or three pulls fall into a certain rhythm quite of his own accord.

Fig. 288 shows this fact with a child, who worked with the ergograph for the first time, and whom I told to pull just as he wished. After a few pulls a regular rhythm sets in.

Here we have the important phenomenon that all work is rhythmical.

If I let the kymograph revolve very rapidly each single pull will be recorded at great length. Working without any guiding rhythm I get a curve like Fig. 289, each separate curve is long-drawn out and has sometimes two

[1] D. Awramoff, "Arbeit und Rhythmus. *Philosophische Studien*, Bd. 18, 1903.

summits. This means that the weight has been lifted and then held up for a certain time or even lifted still higher, and thereby a great amount of force goes to waste.

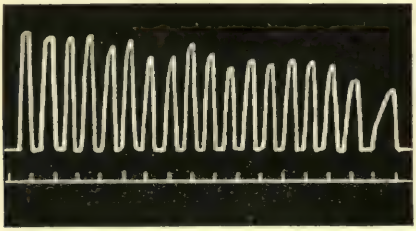


FIG. 288.—The first ergograph curve of a nine-year-old child without a prescribed rhythm. (The time record was drawn afterwards.)

FIG. 289.—Single pulls on the ergograph without prescribed rhythm.

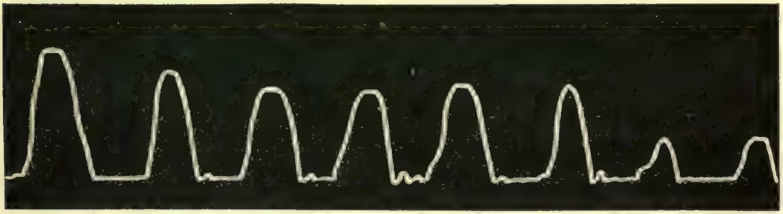


FIG. 290.—Single pulls on the ergograph with prescribed rhythm.

As soon as the work is continued, rhythm as usual appears and each single curve becomes considerably narrower (Fig. 290). The weight is only held up for a short time and much energy is thereby saved.

This shows us the great importance of rhythm in work.

It would seem that young children are not as capable of making regular rhythmical movements as adults are.

The first question for pedagogy to settle is, the age at which children are capable of a rhythmical activity. Only after this age should they be sent to school to work.[1] The school for play, *e.g.* the kindergarten, must consider it as its most important task, to develop the sense for rhythmical movements. Rhythmical games, or exercises, where music forms the rhythmical basis, are of the greatest importance.

The ergograph can also be used to discover the individual rhythm of an observer, by allowing him to pull as he likes. By this means we could test how far the individual rhythms of the pupils of a class differ from each other.

It is also important to know how children behave when a certain rhythm is imposed upon them, as generally must be the case in class teaching.

The children are first allowed to work on the ergograph as they choose—individual rhythm. Then the time is increased.[2] Some children will thereby produce better work. These are the healthy ones, who respond to some stimulation. Others produce less. For these, then, any artificial stimulation is harmful.

Lastly, there will be a third group of those absolutely unable to follow the prescribed rhythm. Such children, *i.e.* children who within certain reasonable limits cannot follow a prescribed rhythm, are not yet ripe for class teaching.

If we wish to investigate special forms of work we

[1] If we compel them to work before this age is reached, we are only forcing them to make useless movements at a great cost of energy.

To make movement rhythmical, as a preparation for work, is the important task in preparing our children for the elementary school.

[2] For all these experiments an apparatus to beat the time is necessary. The handiest apparatus is the metronome.

must use special apparatus. For writing we use Kraepelin's writing apparatus (Fig. 291). It consists of a plate, P, on which the paper is laid, and which by means of levers is in connection with the recorder *h*, which moves as soon as any pressure is exerted on the plate P. The

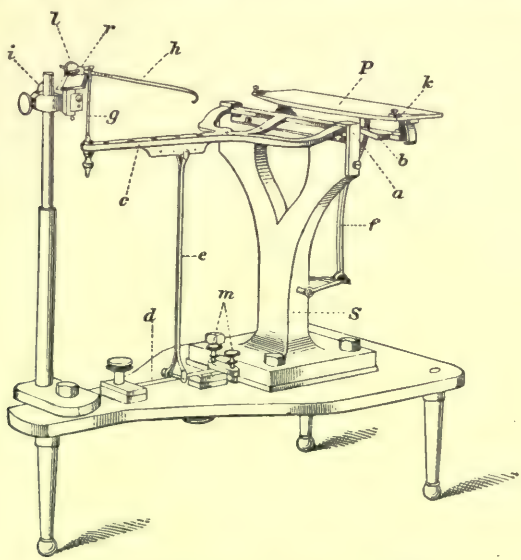


FIG. 291.—Kraepelin's writing apparatus.

(From *Kraepelin's Psychologische Arbieten*, II. Engelmann.)

recorder *h* writes on a kymograph revolving at the rate of 5–6 cm. per second.

Fig. 292 shows the curves of normal individuals when writing the figures 1, 2, 3. Fig. 293 shows similar curves for an insane person. These latter are characterised by very small pressure and want of rhythm. Mayer (Figs. 294 and 295) showed that the influence of alcohol causes a loss of the fine rhythm of pressure in writing, which probably gives our writing movements their certainty and character. In Fig. 294 the figure 8 is written three times, and each time it shows a sixfold irregular

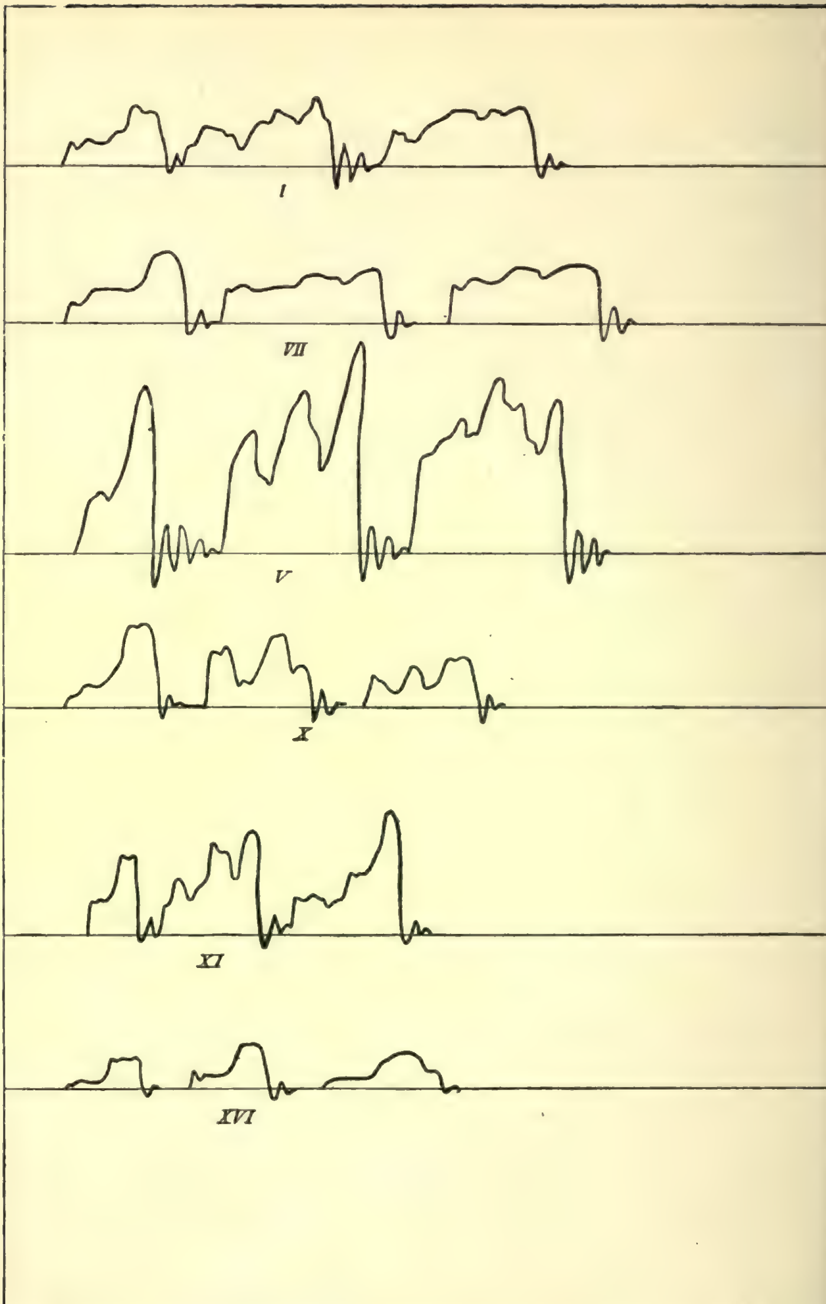


FIG. 292.—Pressure curves while writing the figures, 1, 2, 3, by normal men (I. V. VII.) and women (X. XI. XVI.)

(From Gross, *Kraepelin's Psychologische Arbeiten*, II. Engelmann.)

pressure in a certain rhythm. Fig. 295 shows the same person working under the influence of alcohol. The fine rhythm has disappeared. The pressure is irregular as before, but has no system. Each 8 is written quite differently.

Meumann, following Goldscheider, used an apparatus

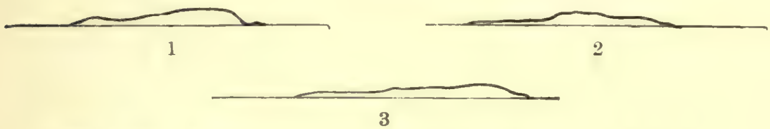


FIG. 293.—Pressure curves while writing the figures, 1, 2, 3, by an insane patient.

(From Gross, *Kraepelin's Psychologische Arbieten*, II. Engelmann.)

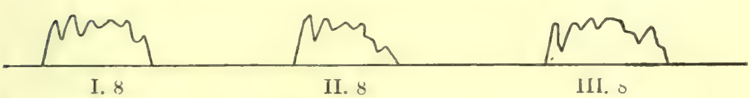


FIG. 294.—Pressure curves while writing the figure 8 three times. Normal experiment.

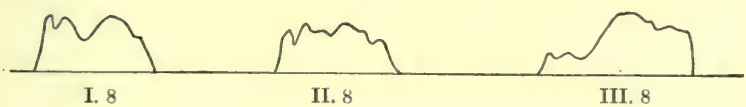


FIG. 295.—Pressure curves while writing the figure 8 three times. Alcohol experiment.

(From Mayer, *Kraepelin's Psychologische Arbeiten*, III. Engelmann.)

whereby the pressure was exerted on to a pneumatic capsule, which was in connection with a Marey tambour. The curves in Figs. 296–299 were written by this method. They show how slowly and with what a waste of energy the six-year-old child writes. There is no appearance of a rhythmical arrangement of chief and minor impulses as in the adult.

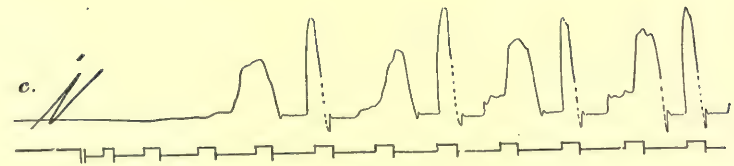


FIG. 296.—i (with dot) written four times. Adult.

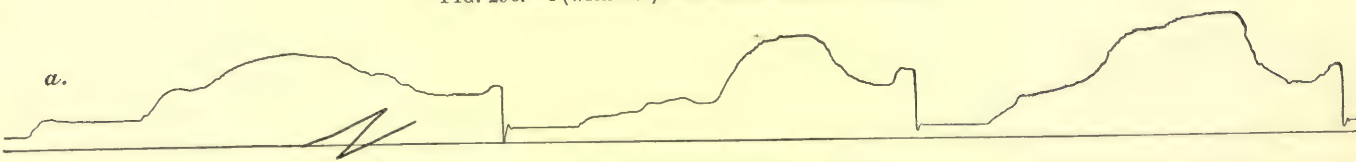


FIG. 297.—i (without dot) written three times. Girl, age 12.

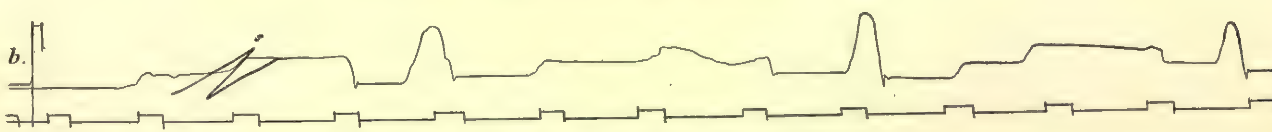


FIG. 298.—i (with dot) written three times. Boy, age 11.

FIG. 299.—i (with dot) written once. Boy, age 6.

(296–9 From Meumann's *Vorlesungen.* Engelmann.)

IV. THE SYMMETRY OF MOVEMENT

If I have worked to exhaustion on the ergograph with my right hand, and then continue with my left hand, it appears that the left hand has become fatigued by the work of the right one. It cannot produce the same as it

Fig. 300.—Involuntary symmetry of movement when modelling.

(From Tadd, *Neue Wege zur künstlerischen Erziehung*. Voigtländer.)

could have done without the previous fatigue of the right hand. This arises from the fact that the innervations, which bring about the contraction of the finger muscles of the right hand, spread over to the left hand, even if they are not so strong as to cause a contraction of the muscles of the left hand, which latter is indeed often the case.

It would be interesting to determine in figures, by means of the ergograph, this loss of energy. If it is great, it

FIG. 301.—Co-ordination of symmetrical groups of muscles.

(From Tadd, *Neue Wege zur künstlerischen Erziehung.* Voigtländer.)

FIG. 302.—Practising the left arm after drawing with both arms.

(From Tadd, *Neue Wege zur künstlerischen Erziehung.* Voigtländer.)

would be desirable, whenever possible, to make use of the corresponding part of the body as well.

The involuntary and perfect symmetry of movement in Fig. 300 shows that such a symmetrical activity is something quite natural.

The American method of teaching drawing has developed this systematically (Fig. 301). Its success is seen in Fig. 302. The left hand alone is sometimes used. Such methods would tend to a more uniform development of the body, which is a thing to be desired.

CHAPTER XII

MENTAL WORK

I. METHODS OF INVESTIGATION

1. Indirect Methods

In measuring accurately any branch of mental work, *e.g.* fatigue, either direct or indirect methods may be used. The direct methods seek their measure in the mental work itself. The difficulty of arriving at exact measurement in this manner led to the use of indirect methods, which measure concomitants of mental work. Naturally such concomitants are chosen as lend themselves to particularly exact measurements.

The indirect methods were introduced by Mosso, who presupposed that muscle power diminished with the decrease in mental ability. If that were true, decrease in mental ability could be determined by the ergograph, which measures muscle power.[1] This hypothesis has been proved to be false. Muscle power does not decrease in proportion to mental power. It therefore cannot be used as a measure of mental power. There are cases where decrease in mental ability leads to increase in muscle power and vice versa.

Many experimenters made use of tests of the spatial threshold with the æsthesiometer, going out from the

[1] On the same supposition the dynamometer was used to measure mental fatigue. This apparatus, which only tests a single muscular contraction (not continuous work), is not even sufficient for accurate investigation of physical ability, and is only of use for determining rough individual differences (states of illness, &c.).

supposition that in a state of mental fatigue a judgment of distance must be more inaccurate than in a state of mental freshness. This method also led to negative results.

It does not seem necessary to continue this list of indirect methods. We must therefore give up the idea of obtaining an exact measure, such as indirect methods had promised to give us. We must fall back upon the mental work and see if we cannot find a reliable measure in that work itself.

2. Direct Methods

The direct methods use the mental work itself as a measure of the mental ability. The advantage of this is that the measure is directly proportional to the measured phenomenon. The difficulty lies in the task of arranging mental work, so as to get a unit of measurement.

Kraepelin gave digits for addition. In the number of digits added in a certain time, and in the number of errors, we have a measure of the work. Kraepelin wrote the digits in a row one underneath the other, and the addition was done mentally. I have changed this method slightly, in that I only write two figures one underneath the other, as the following row shows. The first four rows have been added :—

4	2	8	4	2	3	9	9	5	4	6	5	4	3	1
7	9	2	9	3	8	3	8	2	6	5	4	1	3	5
11	11	10	13											

To avoid losing time by writing, only one of the figures of the totals is generally written, *e.g.* 1 instead of 11 ; 0 instead of 10 ; 3 instead of 13.

As unit of measurement one addition is taken. This presupposes that each addition requires the same amount of mental work. This is naturally not the case. The

supposition is that in a great number of tests this is equalised. The additions must, of course, be irregularly mixed. This is best attained by writing each possible combination of figures from one to nine on pieces of paper, by mixing the papers and then arranging the additions from the papers as they come to hand.

The experiment is carried out in the following manner. The children cover the additions with a piece of paper. At the signal "Now," they begin to work. Every minute or every five minutes the experimenter shouts, "Dash." The children must then make a dash under the last sum

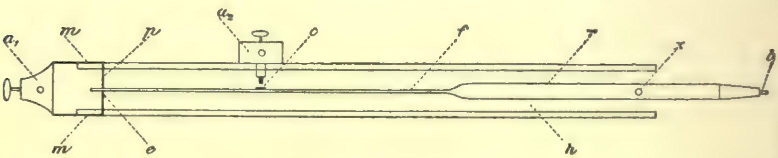


FIG. 303.—Kraepelin's electrical pencil.

(From *Kraepelin's Psychologische Arbeiten*, II. Engelmann.)

they have added, and go on adding until the experimenter shouts, "Halt." The additions should be made in pencil.[1]

The number of additions for every minute, or better, for every five minutes, is then calculated, and these figures serve as a measure for the mental ability, taking for granted that the children have made no mistakes. If one wants to get a picture of the progress of the work, a curve of these figures should be drawn.

The opposite of Kraepelin's addition method is Ebbinghaus' combination method. Here a text of the following form is given to the observer.

[1] If the length of time for each single addition is to be tested, Kraepelin's pencil (Fig. 303) should be used. As soon as this touches the paper, an electrical contact is shut and a mark is made on a kymograph in connection. Every new result that is written down causes a new mark. From the distance between these marks we can reckon the time required for each single addition.

THE SIEGE OF KOHLBERG, 1807

Since the enemy cont . . . rene . . . vigour to . . . at . . . new fortifications on the sand road, our new commander . . . first night after . . . arrival arranged an at . . . them. This was car . . . out in the greatest . . . silence by . . . troop of grenadiers and of . . . of about a hundred . . .

This text must be filled out by the observer. We see what the idea of Ebbinghaus was. He wished to test a higher mental faculty, that of combination. The addition method seemed to him to be too mechanical. But the combination method has this disadvantage, that it is extremely difficult to give a value to our results. It is absolutely impossible to put a text together, in which the combinations required are anything like equally difficult from beginning to end.

Between these two extreme methods there are a great many others. Almost any mental work can be used as a test, *e.g.* copying letters or figures, reading, reckoning, writing letters, words, or sentences from dictation, &c. The nearer a method approaches school-work, without lacking such a uniformity in the matter as to make exact measurement impossible, the more excellent is that method.

In general it is best to begin investigations with the exacter methods, *e.g.* Kraepelin's addition method, even although we run the danger of incorporating a lot of purely mechanical physical work.

If, however, we lay special stress on investigating the higher mental functions (the combination method) we should, if possible, at the same time use one of the exacter methods as a check on our results.

The choice of method must of course, in all cases,

depend largely on the purpose of the particular experiment.

II. THE INTERPRETATION OF WORK CURVES

1. Mental Ability

If I let a class make such additions for quarter of an hour or only for five minutes, the results I obtain give me a measure of their ability for this work, and it is a measure that I can represent in figures. Of special interest are the individual differences. For example, I established the fact that in my class the best pupils were able to add five times as quick as the dullest.[1]

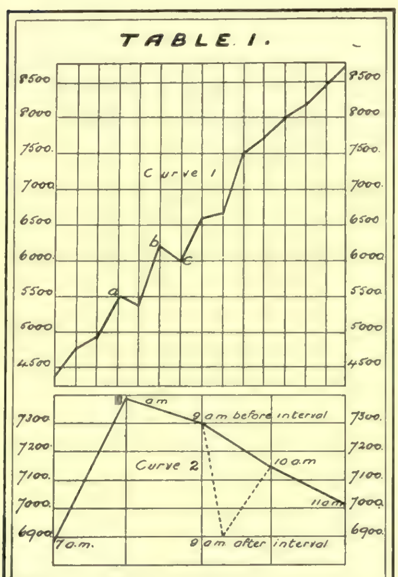


FIG. 304.—Practice and fatigue curves.

(From *Praktischer Schulmann*, 1904. Klinkhardt.)

If I let the children add for five minutes at the same time every day, the effects of practice will appear. From Fig. 304, curve 1, we see that on the first day all the children together could not yet add 4500 examples, on the last day they achieved 8500, which shows a considerable increase. If I compare the first and last totals of each child, great differences in the influence of practice appear. The weakest pupil showed very little increase due to practice, but the second weakest pupil increased

[1] See R. Schulze, "Übung und Ermüdung," *Der praktische Schulmann.* Heft 3. Leipzig, 1904.

from 100 to 300, an increase much above the average. Such figures give us a deep insight into the capacity of each individual pupil.

We can also investigate the progress of mental ability during the day by means of these five-minute experiments. I can let the children add for five minutes at 7, 8, 9, 10, 11 o'clock, and I can see from my results what influence school-work has on the mental ability.

From such experiments we nearly always obtain very complicated curves (Fig. 304, curve 2). Generally the curve begins at first to rise and then sinks gradually. From this we see at once that we have to deal with two factors that affect the progress of every kind of work—practice and fatigue.

2. Ideal Practice and Fatigue Curves

To obtain a clear conception of the course of a work curve, it is desirable first of all to consider what the probable course of a pure practice or a pure fatigue curve would be.

Let us suppose that the children accomplish 500 additions in the first minute (Fig. 305, curve 3). Because of practice, they increase in the second minute to 700. It is impossible for this increase to continue at the same rate. We would, then, soon reach such high figures as in reality never appear. We must therefore suppose that the practice curve becomes gradually flatter, as curve 3 shows, and that eventually it runs horizontally. For we know that with all activities, a certain time comes when no further increase is possible. Now if we have a practice curve as in Fig. 304, curve 1, which runs upwards at a steep angle, we can conclude that the effect of practice is far from having reached its limit. We are only at the preliminary stages of practice. By this means we can

draw conclusions from the course of a practice curve as to the stage of practice at which a child is at the time.

Similarly we can sketch theoretically the probable course of a fatigue curve. We know that fatigue decreases ability. If the children accomplish 1300 additions in the first minute, it will decrease perhaps to 1100 in the second minute, if we suppose that the influence of practice is not at work. If the decrease were to continue at the same rate we would have in the third minute 900, in the fourth 700, in the fifth 500, in the sixth 300, in the seventh 100, and in the eighth – 100, a negative quantity. This has clearly no sense. We must therefore presume that the fatigue curve gradually approaches a horizontal direction (Fig. 305, curve 4).

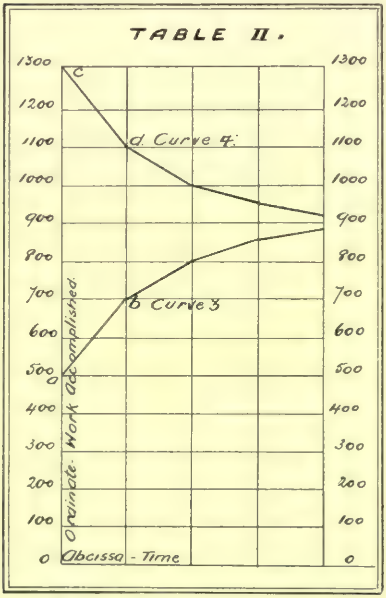


FIG. 305.—Ideal practice and fatigue curves.

(From *Praktischer Schulmann*, 1904. Klinkhardt.)

Now in reality every work curve is under the influence of these two factors—practice and fatigue.

Fig. 306 shows us what complicated forms can result. Let us suppose that the fatigue of children always takes the course represented in curve 5. If the children are in the early stages of the experiment, the pure practice curve will rise very steeply (curve 5*a*). If I reckon out for every period of time what is gained by practice and what is lost by fatigue, I arrive at the complicated curve 5A. A work curve in

the preliminary stages of an experiment must be something like this.

As the children have more practice, the practice curve will not be able to rise so high or so steep (curve 5*c*). If I combine it with the fatigue curve 5 as before, I obtain curve 5C, a curve that runs fairly horizontally, but which shows signs of sinking.

At the end of a long period of practice, the influence of practice cannot of course be very great (curve 5*b*). Calculating as usual with the fatigue curve, we obtain the curve 5B, which is almost like a pure fatigue curve. If our reasoning is correct, then real work curves must approximate to 5A for the preliminary stages, 5C after moderate practice, 5B after considerable practice.

TABLE III.

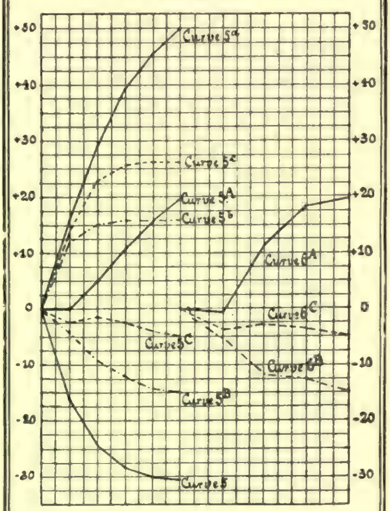


FIG. 306.—Mathematically constructed and real work curves.

(From *Praktischer Schulmann*, 1904. Klinkhardt.)

Curves 6A, 6C, and 6B show real work curves that I obtained from my experiments with children at the three stages in question. We see how similar the theoretical and the real curves are. And we see how it is possible to explain very complicated, irregular curves from the combined influences of practice and fatigue alone.

If a pause occurs during a piece of work, two things take place—recovery from fatigue and a loss in practice. According as the recovery or the loss in practice is greater,

the production of work after the interval will be greater or smaller. In Fig. 304, curve 2, for example, the loss of practice after the interval at nine o'clock was greater than the recovery, and therefore the work produced directly after the interval was very little.

3. Real Practice and Fatigue Curves

If I wish to produce a pure practice curve I must let the same work be done every day, with sufficient intervals for rest.

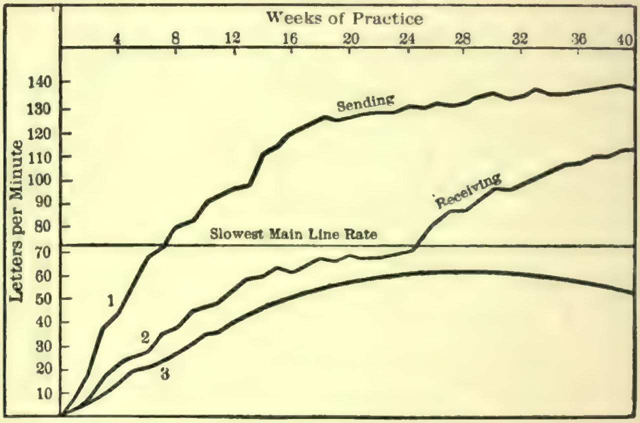


Fig. 307.—Practice curves in receiving and sending telegrams.

(From Bryan and Harter, *Psychological Review*, IV.)

If I had continued my experiments with my children, the fairly steep practice curve in Fig. 304, curve 1, would have gradually approached the horizontal. This occurs normally only after a good many days of practice.

Fig. 307 shows the work produced by men preparing for their examination as telegraph assistants. The telegraph company demands a minimum of a little over seventy letters per minute in sending or receiving a telegram.

Sending is fairly easy to learn. The pupil achieves this after the eighth week of practice, and at the fortieth week the practice curve runs quite parallel. The curve shows in general the course we have described, at first steep and then gradually flatter.

Receiving is much more difficult to learn. The practice curve soon becomes flat, and at the twentieth week the influence of practice seems to be at an end. The desired result has, however, not yet been attained. At this point we see a new practice curve arising, which even at the fortieth week does not seem to have reached its maximum.

Such additional practice curves seem to point to the fact that there are two different factors in the activity in question, and these factors would seem to require special practice for each alone. Such a curve would make us attempt an analysis of the complicated process. If this were achieved, it would make it easier to exert a pedagogical influence on the process.

If we wish to obtain a pure fatigue curve, we must first of all practise a certain kind of work, say addition, so long until the influence of practice is no longer felt, *i.e.* until the practice curve runs horizontally. Then carry out this work for hours at a stretch without a pause.

To investigate physical and mental fatigue separately, I first of all let figures be copied down, not added, for a period of four hours. Here the chief work was the physical work of writing (Fig. 308, curve 10). To test mental fatigue I used addition, without writing down the results. This was done for three hours in the morning (curve 8), and for four hours in the afternoon (curve 9). The physical fatigue curve shows the pure form of fatigue curve—at first steep and then a gradual falling-off. In the addition curves we note a slight influence of practice.

I therefore made experiments with myself. I first of all made preliminary experiments for a few months in addition, until no more influence of practice could be seen. Then I added uninterruptedly for six hours. The result (Fig. 308, curve 7) shows great irregularities, but on the whole we see the steep drop at the beginning, and

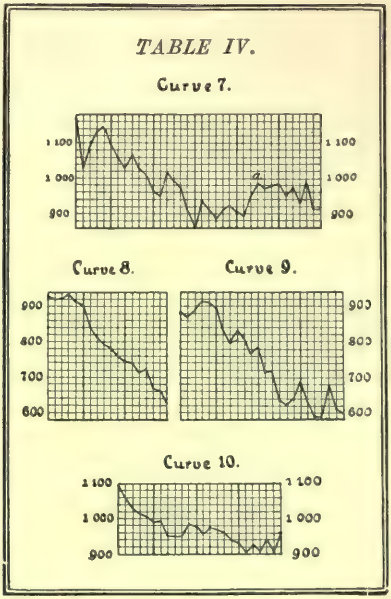


FIG. 308.—Physical fatigue, Curve 10: Writing down figures for four hours. Mental fatigue: Addition without writing down the results.—Curve 8. Forenoon (3 hours). Curve 9: Afternoon (4 hours). Curve 7: Forenoon (6 hours)

(From *Praktischer Schulmann*, 1904. Klinkhardt.)

then the gradual falling-off until a horizontal course is attained.

Point *a* in the fifth hour is remarkable. Before this moment was reached the pain in my hand from writing down the totals had become unbearable, and involuntarily I hit my hand against my knee. Very probably this movement helped to get rid of some of the fatigue poison in my hand. The muscle became at once more capable

and the work produced rose considerably.[1] This case shows with great clearness how every mental work pos-

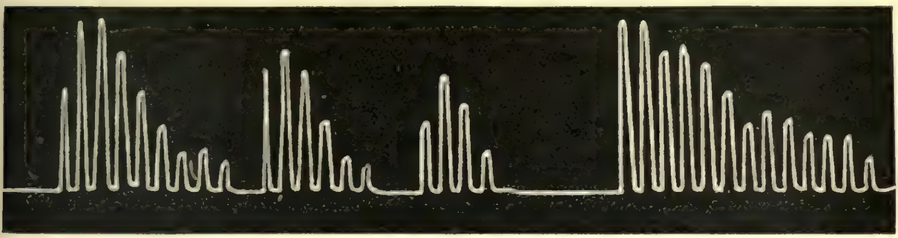


FIG. 309.—Effect of massage on the work of a muscle.

sesses a physical factor, and that therefore the problem of mental work can only be solved along with the problem of physical work.

4. Other Components of Work Curves

Kraepelin and his pupils have attempted to investigate the further components of work curves. Besides practice and fatigue he emphasises the following factors :—

1. Habituation (the getting accustomed to the work). This runs similar to the practice curve, and cannot perhaps be strictly separated from it (Fig. 310, curve G).
2. Stimulation (R), which causes the rise of the curve at the beginning.
3. Concentration of the will (W), which sinks rapidly at the beginning and then undergoes irregular fluctuations.

The curves of practice (U) and fatigue (E) according to Kraepelin run in almost straight lines, which does not

[1] Also in work on the ergograph the ability of a fatigued muscle can be increased by massage. The first three curves in Fig. 309 are fatigue curves which were recorded with pauses of five seconds between. After the third curve the five seconds was used to shake the hand vigorously. Even this imperfect massage increased the work produced considerably, as the curve shows.

correspond to our opinion. A shows the real work curve which Kraepelin thus dissects. For details I must refer the reader to Kraepelin [1] or to Meumann.[2]

It should also be noted in regard to Kraepelin's diagram

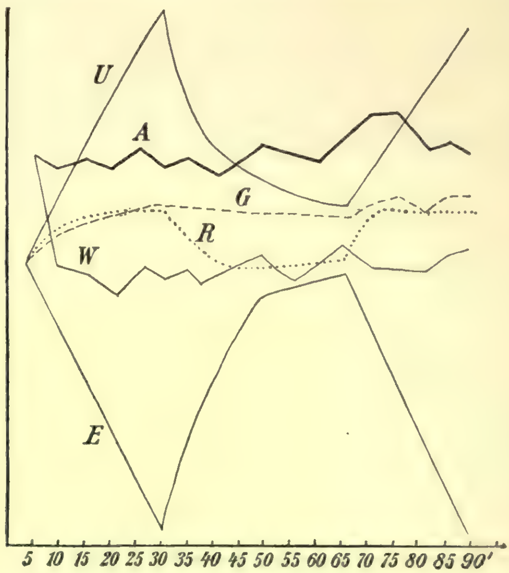


FIG. 310 —Components of the work curve, according to Kraepelin.

(From Wundt, *Physiologische Psychologie.* Engelmann.)

that there was an interval after thirty minutes of adding. We see how this affects the different factors, how fatigue changes to recovery, how a loss of practice appears, &c. After about thirty minutes' pause the work begins again, and all the factors operate as before.

[1] Kraepelin, *Die Arbeitskurve.* Leipzig, 1902. See also Kraepelin, *Psychologische Studien*, Bd. I.–IV.

[2] Meumann's *Vorlesungen.* The important pedagogical conclusions to be drawn from the investigation of work are treated at length.

CHAPTER XIII

PSYCHICAL CORRELATIONS

If now at the end of our book we cast a glance back at the methods, many excellently developed, that may be used in experimental psychology and pedagogy, we have, in spite of their number or perhaps just because of their great number, a certain feeling of dissatisfaction. We can measure accurately the difference sensitivity for colours, the direction of our associations, the excellence of our memory, but where is the method that takes account of the fact that our soul is not a mere sum of difference sensitivities and reproduction tendencies? Where is the method that does justice to the soul as a whole, a fact that is expressed by the naïve mind by such words as general intelligence, character, personality, and an investigation of which must remain the most important problem for psychology? The other methods allow us to test the effect of education upon one single capacity, say the memory. But where are the methods that give us the means of investigating accurately the whole of education from certain definite standpoints?

The impulse towards uniformity, which is so deeply imprinted in the human soul, has also taken hold with irresistible power of those experimenters who have devoted themselves to experimental psychology. It led to premature attempts to comprehend and measure general intelligence. In single tests the American experimenters

sought to find a measure for general intelligence, and almost every method that ever had been used in psychology was treated as such a test. All these attempts were doomed to failure. More far-seeing experimenters attempted another way. A whole series of tests was arranged, *i.e.* an attempt was made to describe the human mind by figures representing the difference sensitivities, the memory, ability in combination, &c. But the result of this method is also a negative one. We learn that we cannot define the human soul as a sum total of separate phenomena.

Only within the last few years has a way been shown that promises much success. The hypothesis that a measurable general intelligence exists is abandoned. The problem is attacked directly and empirically, by asking the question as to what relations exist between the individual psychical functions. By this method, starting from the bottom, we hope to work upwards to the "central factor," which, as we must presuppose, determines the whole structure of psychical relations.[1]

I. THE CALCULATION OF CORRELATIONS

In the field of psychical relations, as in other departments of psychology, we shall only be able to make a definite advance when we use exact mathematical methods. Here the theory of correlations gives us the

[1] The problem of correlation will be treated here in detail, as it has up to now been absolutely neglected in educational works. Even Meumann scarcely touches it in his *Vorlesungen.* See Deuchler's excellent criticism of the *Vorlesungen* in the *Pädagogisch-psychologischen Studien*, Nos. 7 and 8. 1908.

required assistance. We shall explain by means of an example the most important formulæ.[1]

1. The Correlation Formula

Krueger and Spearman tested eleven persons according to the following five methods, all of which we have already described :—

1. Addition—Kraepelin's addition method.
2. Combination—Ebbinghaus' combination method.
3. The difference sensitivity for tones, measured by the number of oscillations between two just noticeably different tones.
4. The spatial threshold, measured on the cheek-bone with the æsthesiometer.
5. Learning by heart, measured by learning figures.

The experimenters then put the question : Do there exist relations between these different abilities of such a kind that an individual with an excellent memory also possesses an extraordinarily fine difference sensitivity for tones? Or does, perhaps, a good memory go hand in hand with a bad difference sensitivity for tones? Or are there absolutely no relations between these two abilities?

For the moment we shall pass over the actual results of this investigation and turn our attention to the method employed. Let us take one problem, the relation between difference sensitivity for tones and the addition of two digits.

[1] For the study of psychical correlation see F. Krueger and C. Spearman, "Die Korrelation zwischen verschiedenen geistigen Leistungsfähigkeiten," *Zeitschrift für Psychologie*, Bd. XLIV., 1906; C. Spearman, "General Intelligence, objectively determined and measured," *American Journal of Psychology*, vol. xv., 1904.

Table I. shows the results obtained in the test of difference sensitivity for tones of the eleven observers A to K.

TABLE I.

Observer.	Number of Oscillations.
A	2·5
B	2
C	27
D	1·5
E	28
F	7
G	6·5
H	2·5
I	1·5
J	1·5
K	11

In the same manner the rapidity of addition was determined for all the observers.

It seems at the first glance impossible to bring these two rows into relation with each other. How can I bring the fact, that A was able to distinguish one tone from another at 2·5 oscillations per second, in relation to the other fact, that A was able to complete 125 additions in a certain time? Is this number of additions such a one as corresponds to a difference sensitivity of 2·5 oscillations per second? Or must I say that A shows a small difference sensitivity for tones and a great rapidity in addition? Or is the rapidity in addition less than the tone sensitivity? We see, in short, that if our investigation only included one observer, we could give absolutely no answer to such questions.

But we have eleven observers, and so there is the possibility of arranging their results in a row according to ability. The following table gives this row for the tone sensitivity. Observer D with 1·5 oscillations comes first, and E with 28 oscillations comes last.

TABLE II.

Observer.	Number of Oscillations.
D	1·5
I	1·5
J	1·5
B	2
A	2·5
H	2·5
G	6·5
F	7
K	11
C	27
E	28

If I wish to number the different observers according to their ability, there appear slight difficulties. For D, I, and J show equal ability. We have no right to give any of them the first place. Let us give them all the second place, leaving it open as to which of them should get place 1 or place 2, as a more accurate investigation might show. Next comes B in the fourth place. Places 5 and 6 must be divided between A and H, and therefore we give each of them place $5\frac{1}{2}$. G follows with 7, F with 8, K with 9, C with 10, and lastly E with 11. Table III., column 2, shows this arrangement; each observer has received a certain place number. In column 3 we have their place numbers for addition, which have been worked out in exactly the same way. In this column all the numbers from 1 to 11 appear, there are no halves, &c. This is, of course, due to the fact that in the additions much greater differences appear in the results, so that in no case did two observers have the same result.

The two rows show three cases of similarity in rank (B, C, and I), but there are also small and large differences as well. The difference of observer E's places is great. In adding he is exactly in the middle, whereas in tone sensitivity he is the worst.

Now is there a correlation between these two abilities in general? Does on the whole a quickness in adding go hand in hand with a fine tone sensitivity? And how can we represent mathematically the degree of correspondence that seems to exist?

To solve this question we shall now carry out a calculation, the use and meaning of which will afterwards be made clear.

First of all we make a calculation with the places.

TABLE III.

1. Observer.	2. Order in Tone Sensitivity.	3. Order in Addition.
A . . .	5½	7
B	4	4
C	10	10
D	2	1
E	11	6
F	8	9
G	7	11
H	5½	3
I	2	2
J	2	5
K	9	8

We fix on the middle place, in our case the sixth, and reckon the deviation of each observer from this median. In addition A has the seventh place. We give him the value $+1$. He deviates by one place from the median and his place is greater than six by one. B has the fourth place; he therefore gets the value -2, as his place is two less than the median.[1] This new arrangement we find in the third column of the table under the heading x or deviations from the median. In exactly the same

[1] Minus in this case therefore denotes the better abilities and plus the worse ones.

manner we calculate the deviations from the median in tone sensitivity (y in column 5). Then in column 6 we calculate the value x^2 for each observer. A has as x a value $+1$, which when squared gives 1. B has -2, which when squared gives 4, and so on. All these values (x^2) are positive, because a minus into a minus gives a plus. In the same manner we reckon out the values

TABLE IV.

1. Observer.	2. Order in Addition.	3. x or Deviation from the Median.		4. Order in Tone Sensitivity.	5. y or Deviation from the Median.		6. x^2	7. y^2	8. xy.	
		+	−		+	−			+	−
A	7	1	...	$5\frac{1}{2}$	...	$\frac{1}{2}$	1	$\frac{1}{4}$	...	$\frac{1}{2}$
B	4	...	2	4	...	2	4	4	4	...
C	10	4	...	10	4	...	16	16	16	...
D	1	...	5	2	...	4	25	16	20	...
E	6	0	...	11	5	...	0	25	0	...
F	9	3	...	8	2	...	9	4	6	...
G	11	5	...	7	1	...	25	1	5	...
H	3	...	3	$5\frac{1}{2}$	...	$\frac{1}{2}$	9	$\frac{1}{4}$	$1\frac{1}{2}$	...
I	2	...	4	2	...	4	16	16	16	...
J	5	...	1	2	...	4	1	16	4	...
K	8	2	...	9	3	...	4	9	6	...
							110	$107\frac{1}{2}$	$78\frac{1}{2}$	$\frac{1}{2}$

y^2 (column 7). A has as y the value $-\frac{1}{2}$, which when squared gives $+\frac{1}{4}$, and so on. Lastly, in column 8 we reckon out the values xy. A has as x the value $+1$, and as y the value $-\frac{1}{2}$, which multiplied together is equal to $-\frac{1}{2}$. B has -2 and -2, which is equal to $+4$, and so on.

We then take the sum of all the x^2, y^2, and xy, and obtain :—

$$\Sigma x^2 = 110$$
$$\Sigma y^2 = 107\tfrac{1}{2}$$
$$\Sigma xy = 78$$

We now maintain that the relation between the two abilities, which we call the correlation and denote with the letter r, is correctly expressed in the following formula :—

$$r = \frac{\Sigma xy}{\sqrt{\Sigma x^2 \cdot \Sigma y^2}}$$

Let us see in a few cases to what values this formula will lead us.

Suppose we take it for granted that the correlation between the two abilities is perfect. Then the best person in addition would also be the best in tone sensitivity, and so on with the rest. We would then, going from the median, obtain for x^2 the value 1 twice, 4 twice, 9 twice, 16 twice, and 25 twice, exactly as in column 6. The total (Σx^2) would also be 110. Now according to our supposition the order of places in tone sensitivity would be the same, and therefore all y and y^2 would be exactly the same as the x and x^2. And the sum of y^2 (Σy^2) would also be 110. Since each x would be equal to the corresponding y, then xy would be exactly the same as x^2 or y^2. So in column 8 we would get exactly the same values as in columns 6 and 7, and the sum (Σxy) would again be 110. The formula

$$r = \frac{\Sigma xy}{\sqrt{\Sigma x^2 \cdot \Sigma y^2}}$$

would therefore give

$$r = \frac{110}{\sqrt{110 \cdot 110}} = +1$$

A perfect correlation would then according to our formula be expressed by the value $+1$.

Let us now consider a second case where a perfect inverse correlation exists. The best in addition will have the worst tone sensitivity, and so on in proportion with the rest. The best adder will get for x the value -5,

and for y the value $+5$. For the next observer $x = -4$, $y = +4$, and so on. Therefore the totals of x^2 and y^2 will remain exactly the same as in the former correlation, $\Sigma x^2 = 110$; and $\Sigma y^2 = 110$. For xy the same figures will also appear, but this time they will be all negative. The best adder has at the same time the worst tone sensitivity, and gets for xy the value $-5 \times +5 = -25$, the next has $-4 \times +4 = -16$ and so on. The sum of xy (Σxy) will be in this case -110. We therefore have—

$$r = \frac{\Sigma xy}{\sqrt{\Sigma x^2 \cdot \Sigma y^2}} = \frac{-110}{\sqrt{110 \cdot 110}} = -1$$

A perfect inverse correlation would then, according to our formula, be expressed by the value -1.

We need not discuss further cases. We see clearly from this, that in cases where the correlation is small, we shall obtain a value between $+1$ and -1, and that in the case where there is absolutely no correlation, we shall obtain the value zero.

If we work out our example, the correlation between tone sensitivity and addition, we obtain—

$$r = \frac{\Sigma xy}{\sqrt{\Sigma x^2 \cdot \Sigma y^2}} = \frac{78}{\sqrt{110 \times 107\frac{1}{2}}} = \cdot 72$$

We see that the correlation coefficient r is very nearly equal to $+1$, and that therefore a high correlation between these two seemingly unrelated functions exists.

The probable error (see p. 22 ff.) for every correlation must also be calculated. We use the formula—

$$\mathrm{PE} = \cdot 6745 \frac{1 - r^2}{\sqrt{n\,(1 + r^2)}}$$

in which n denotes the number of observers. In our case, therefore, eleven.

Substituting our figures we have—

$$PE = \cdot 6745 \frac{1 - \cdot 72^2}{\sqrt{11}\,(1 + \cdot 72^2)} = \cdot 08$$

We see that the probable error (·08) is considerably smaller than our correlation coefficient (·72). If this were not the case, if the probable error were half as large or as large or larger than *r*, our whole calculation would be worthless, for this would mean that it contained too large an error. At the very most the probable error may be equal to half of *r*, but the usual requirement is that it should not be much more than a fifth of *r*, if we wish to be sure of a trustworthy calculation.

2. A Supplement to the Correlation Formula

If a perfect correlation obtains between the two abilities investigated, and if we suppose that there is absolutely no possible error in measurement, the coefficient will be 1. A number larger than 1, from the nature of our calculation, cannot appear. As soon as any chance error appears, be it positive or negative, it will, by disturbing the arrangement of the places at some place, always lessen the value of the correlation coefficient. Errors in observation do not therefore equalise each other in this correlation reckoning. The more experiments I make, the greater the number of probable errors. I cannot get rid of them by increasing my experiments. It is therefore necessary to supplement the correlation formula.

Krueger and Spearman did this in the following manner. Krueger tested the eleven persons in adding and in discriminating tones, and then Spearman repeated the

experiments under the same conditions. They therefore obtained four rows :—

1. Addition (K).
2. Addition (Sp).
3. Tone Discrimination (K).
4. Tone Discrimination (Sp).

First of all they calculated four correlation coefficients, by taking together 1 and 3, 1 and 4, 2 and 3, 2 and 4, *i.e.* each addition with each discrimination. They then took the average of these four coefficients. It amounted to ·67, slightly less than our previous coefficient ·72, as was to be expected, because of the additional errors that must arise.

We may represent this average by $M(r_1\ r_2\ r_3\ r_4)$.

We may further reckon out a correlation between addition K and addition Sp, and also one between discrimination K and discrimination Sp. If our method of testing is absolutely accurate, then each of these coefficients must have the value 1. For it should make no difference whether the observers were tested by Krueger or by Spearman. Their arrangement in order should be the same. That is to say, the more inaccurate our method is, the smaller will be our correlation coefficient. Therefore such a test of the same ability by several experimenters is a test of trustworthiness or reliability. Let us denote these correlation coefficients by r_z, and call them coefficients of reliability.[1] In the same way we may reckon out the reliability coefficient for tone

[1] It would be a very thankful task for some one to take the trouble to subject our method of giving marks in schools to a reliability test according to the correlation method. Two or more teachers could give marks to the same children for the same subject according to the method used in the school. The children would then be arranged in order and the correlation formula employed. If the reliability coefficient is not large, it would show that the method of marking is unsatisfactory.

discrimination, which we shall call r_{z1}. Then $M(r_z\ r_{z1})$ is the average of the two reliability coefficients. In our example it amounted to ·81.[1]

We see that the reliability coefficient shows only $\frac{4}{5}$ of its true value. We therefore take it for granted that our first average is four-fifths too small. If I divide it by $\frac{4}{5}$, the error will be equalised. In other words, our formula is supplemented if the average $M(r_1 r_2 r_3 r_4)$ is divided by the average of the reliability coefficients $M(r_z r_{z1})$. Let us call this supplemented correlation coefficient r_e.

$$r_e = \frac{M(r_1 r_2 r_3 r_4)}{M(r_z r_{z1})}$$

In our example—

$$r_e = \frac{\cdot 67}{\cdot 81} = \cdot 83$$

We see how the hidden correlation comes more to the front by this supplemented formula.

3. Correction of the Supplemented Correlation Formula

Besides casual errors there may be constant errors in our calculation. If I experiment with a six, a ten, and a fourteen-year-old child, a correlation of some sort will certainly result, whatever mental ability I may investigate.[2] The fourteen-year-old child will always be the best, and the six-year-old child the worst. Here a correlation will be concocted, which in reality, perhaps, does not exist. No one, however, will be so lacking in sense as to arrange an experiment in such a manner, he will more likely take care to avoid such constant errors as far as possible by making

[1] If the reliability coefficient is much smaller, *e.g.* ·50, then the method of investigation is unreliable and should be abandoned.

[2] A similar case would be the classing together, in a test of an idiot, a defective and a normal child.

his problem as definite as possible. The problem should not be, "What correlation exists between addition and tone discrimination?" but rather, "What correlation exists between addition and tone discrimination in English boys of the age of 14?"

But yet we may have doubts as to whether such a constant error has not somewhere crept in during the course of the experiment, and we must be able to compensate it afterwards.

Krueger and Spearman in their experiments, for example, had both German children and children of other nationalities. It was seen that the Germans excelled the others both in addition and in tone discrimination.

To get rid of such a factor I must work out a correlation whereby my first row is arranged according to rapidity in addition, and my second according to nationality, beginning with the German boys. Let us call this correlation coefficient r_x. Then r_x^2 is the square of this coefficient. Our supplemented correlation formula[1] will be corrected, if I divide it by $\sqrt{1-r_x^2}$. Let us call this supplemented and corrected coefficient r_{ek}.

$$r_{ek} = \frac{r_e}{\sqrt{1-r_x^2}}$$

If we define our problem clearly and carefully enough, if we do not make it too wide, the necessity of using this formula can be avoided.

II.—CORRELATIONS IN PSYCHOLOGY

1. Krueger and Spearman's Results

The reader who has followed our tiring calculations, may now be tempted to ask, "What is the use of this

[1] We can only give the formula here and cannot enter into a discussion of it. In actual experiment it should not be necessary to use it, if we are careful enough in determining strictly our problem.

endless reckoning? What have I really gained by it? Is it not really all the same, whether I obtain as my result ·8, or ·6, or ·1, since it must always be left to me, whether I choose to suppose a correlation as existent at ·1 or at ·6?"

This doubt is quite justifiable. And in reality our whole calculation up to this point does not possess the slightest value.

This changes at once as soon as we have investigated several correlations. For we are now able to compare the size of the separate correlations with each other. Then we can say whether addition stands in a closer degree of relationship to tone discrimination or to memory, &c. In this way we can obtain results, which for the theory and practice of education and for psychology may be of the greatest importance.

Krueger and Spearman arrived at the following results in their investigations:—

TABLE V.

Orders of Merit compared.	Correlation Co-efficients.	Probable Error.
Addition and combination	+·79	±·06
„ „ tone discrimination	+·67	·08
„ „ spatial sensitivity	+·19	·20
„ „ learning by heart	+·14	·20
Combination and tone discrimination	+·59	·12
„ „ spatial sensitivity	0	·25
„ „ learning by heart	−·07	·25
Tone discrimination and spatial sensitivity	+·29	·18
„ „ „ learning by heart	+·17	·20
Spatial sensitivity and learning by heart	−·13	·19

We see at a glance that the abilities can be divided into two groups, those between which there is an obvious correlation (addition - combination, addition - tone discrimination, tone discrimination - combination), and

those between which a correlation is absolutely wanting. This latter is the case wherever spatial sensitivity and learning by heart appear. Both the correlation coefficients and the probable errors show this fact clearly.

In the three cases where combination, addition, and tone discrimination are compared, the correlation coefficient is at least five times as large as the probable error. There can be no doubt, then, that these three abilities are connected together by some common cause, by some "central factor" as Krueger and Spearman call it. At the present we can only make guesses as to what this central factor is made up of. This at least seems to be clear, that such a general function as attention, or similar processes, cannot be brought in as a means of explanation, for were this the case, then learning by heart would also have to show a correlation. The two authors have put forward a hypothesis very cautiously. They think a psycho-physiological explanation must be given. Perhaps it is some more or less strong "plastic function" of the nervous system of the persons tested, a function which forms the basis for developing great rapidity in addition, combination, &c. This particular "plastic function" only shows its effects in those cases where we have to deal with the calling up of associations (as in addition) which have been imprinted by long practice. If, however, it is a case of the immediate formation of new associations, as in learning figures or senseless syllables by heart, this "plastic function" is of no use, can exert no effect, and therefore memory shows such low correlation coefficients.

The question why spatial sensitivity and memory show no correlation with other abilities, needs a little more discussion. It is possible that a correlation does exist, but that it does not come to light because of the inaccuracy of the experimental method. We have seen above how every error tends to lessen the correlation

coefficient. And this seems really to be the case with spatial sensitivity. The order of merit in the two tests made by the two different experimenters differed so much that the reliability coefficient was extremely small. Therefore their method of testing this ability was not a suitable one. This still leaves the question open as to whether a correlation exists between spatial sensitivity and the other abilities.

With memory, however, the case is quite different. Krueger and Spearman arranged their observers almost exactly in the same order. The reliability coefficient had the high value of ·92. Therefore the method is excellent. It is better than all the other methods. It is superior to all methods of giving marks in school which were tested in another investigation of the authors in question, better than any method that was used in any subject, from classics to music.

If then, in spite of all this no correlation between memory and other abilities appears, there is nothing to be done but to suppose that really no correlation exists.

2. Öhrn's Results

Krueger and Spearman subjected the results of previous similar investigations by Öhrn to a calculation according to the correlation formula.

Öhrn tested his observers for two hours at a stretch in each ability. It was therefore possible to determine the correlations for every quarter of an hour under the influences of practice and fatigue. We see in Fig. 311 that here, as well, no correlation appears in all those cases where learning by heart is brought into relation with any other ability (mean value-learning by heart). The values for all the eight quarters of an hour fluctuate about the value 0.

Reading also shows only a small correlation. Between

addition and reading and between counting[1] and reading there is absolutely no correlation shown. A correlation, although small, is present between writing and reading.

On the other hand there is a correlation between the three functions of writing,[2] counting, and adding. In all these cases the correlation was greater than five times the probable error.

Besides this, we see in the curves the extraordinary

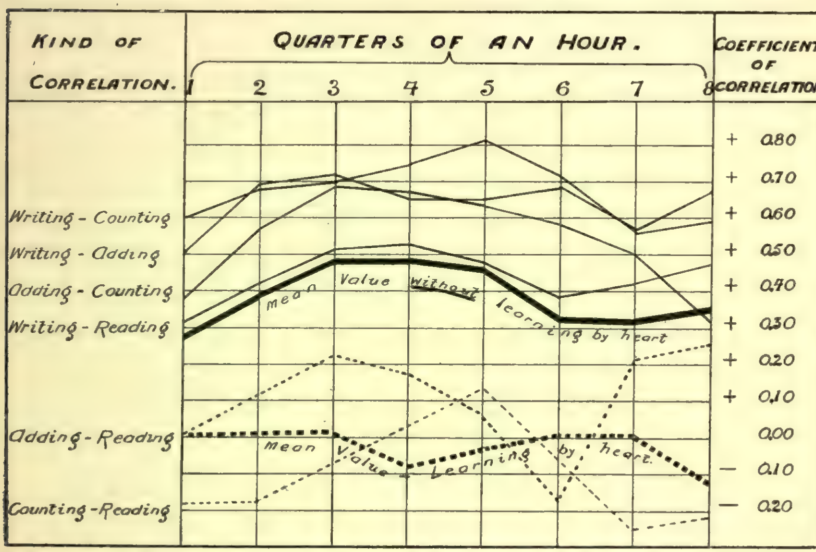


FIG. 311.—Correlation between different mental abilities.

(From Krueger aud Spearman, *Zeitschrift für Psychologie*, XLIV. Barth.)

phenomenon that the correlations increase as long as the influence of practice is felt, *i.e.* during the first two or three (in one case to the fifth) fifteen minutes, while later on, when fatigue appears, they decrease.

It is quite plausible that want of practice should decrease the correlations. Want of practice in carrying out an activity affects different people differently, and therefore the order of merit of the first experiments will

[1] Letters were counted. [2] Writing to dictation.

not show their real capacity. This fact throws a side-light upon some methods of examination which are often actually employed in schools. Their "strength" lies in the attempt, by means of puzzling questions, to baffle the pupil. Such methods are more suited to test the ability of combination of the examiner, than the mental ability of the pupil. The same "value" must be attached to other examinations that fatigue the pupil too much.

It is impossible here to touch upon all the problems that might possibly be solved by means of the correlation formula. Its great value lies in the fact that it is able to discover relations between different functions, where, perhaps, such relations were previously never dreamt of. It divides all functions into those that can be related and those that cannot be related, and thus leads to a separation of these latter by means of strict definitions. In the case of the former it will help us to advance to some "central factor," whose presence causes the relation between the functions.

No part of psychology seems to be shut out from the methods of correlation. Correlation can begin by attacking the problem of psycho-physical relations. It may, for example, be able to solve the problem of the relation between size of brain and intelligence, which up to now has been attempted with inadequate methods. And it may end with the most difficult questions of characterology by discovering the presence or absence of relations between the separate characteristics of the individual.[1]

III.—CORRELATIONS IN PEDAGOGY

The importance of the theory of correlation for pedagogy cannot at the present time be properly estimated. We cannot yet tell its possibilities.

[1] See G. Heymans, "Über einige psychische Korrelationen," *Zeitschrift für angewandte Psychologie*, Bd. I., 1908.

By dividing mental traits into those that are related and those that are not, it gives pedagogy a standpoint from which to judge the separate subjects of instruction in regard to their effect on more general ends and on the ultimate end of education.

The theory of the possibility of purely formal instruction, of the formal value of a subject, will now only be able to be upheld, as long as correlations can be proved.

If single abilities or subjects of instruction show large correlations, we must demand a better grouping together of these subjects. If as the child grows older the correlations are shown to decrease, then the instruction should become more and more specialised. Our curriculum must pay attention to the correlations existent at each age, and group its subjects of instruction accordingly. The only experiments on these lines known to the author are those carried out by Spearman[1] in America. The results were as follows :—

	Classics.	French.	English.	Mathematics.	Tone Discrimination.	Music.
Classics	—	·83	·78	·70	·66	·63
French	·83	—	·67	·67	·65	·57
English	·78	·67	—	·64	·54	·51
Mathematics	·70	·67	·64	—	·45	·51
Tone discrimination .	·66	·65	·54	·45	—	·40
Music	·63	·57	·51	·51	·40	—

What an amount of ideas such a table suggests! It is worth noting that mathematics and music show a greater

[1] Spearman, "General Intelligence," *American Journal of Psychology*, vol. xv.

correlation than music and tone discrimination. Mathematics and music show by no means such a small correlation with other subjects, as is generally taken for granted. Further experiments along these lines are greatly to be desired. No one knows to-day how the different mental traits are related to each other in early childhood, and how these relations change as the child develops.

In child psychology, problems such as the following must be attacked: Does correlation between different traits decrease or increase? Does it happen that correlations change in time into inverse correlations?

Pedagogy must deal with such questions as: Will an existing correlation be decreased or increased by a certain educational method? Spearman and Krueger maintain that practice, at least at first, tends to increase the correlation coefficient; Binet maintains the opposite.

Besides this we have the great problem as to the secondary effects of instruction. Each subject of instruction, each educational method tries to attain a definite end, but in the course of this striving there appear, unnoticed by the educator, other effects that were not aimed at. These Baade [1] has called the secondary effects of instruction. Everywhere, where correlations exist, we must take for granted that secondary effects will appear. We must investigate whether these secondary effects cause an increase or decrease, or perhaps an inversion of the natural correlations. For example, the cultivation of the memory for numbers may assist the memory for words, but it may, by fostering a one-sided way of thinking, hinder the development of the æsthetic feelings.

The degree in which a subject changes the existing correlations will help us to judge its value for general culture.

[1] *Vide* W. Baade, *Die Frage nach den sekundären Wirkungen des Unterrichts.* Nemnich, Leipzig, 1907.

And lastly, it may also be possible by means of the correlation theory to come a little nearer to the great question, as to how far our school system prepares a child "for life." The further away from real life our school-teaching is, the fewer correlations will be shown when we arrange the children according to their general practical abilities on the one hand and to their place in school on the other.

We see how the problems spring up here as fast as mushrooms. The methods to solve them are at hand. What we need now are workers, who will grasp the new instruments experimental pedagogy has placed in their hands, and begin to dig the virgin soil of experimental investigation.

The way of progress can only be the way that Wundt has shown us in his *Introduction to Psychology* [1]—from the simplest problems to the more complex.

By this method we shall find out first which problems in pedagogy are capable of being solved experimentally. He who at the present stage attempts experimental didactics, does no good service to experimental pedagogy.

Whoever wishes to take part in experimental pedagogy should bear in mind the words of Professor Wirth, Director of Wundt's Laboratory, spoken at the opening ceremony of the Pedagogical Institute of the Leipzig Teachers' Association, "Hold fast to your endeavour to use experimental psychology for pedagogical purposes. Hold fast to Wundt's scientific principles, as to the possibilities and limits of experimental psychology. That will be the best guarantee that your scientific work will not be barren of results."

[1] W, Wundt, *An Introduction to Psychology*, p. 151 *et seq*. George Allen & Co. London, 1912.

APPENDIX I

A NEW CHRONOSCOPE

Shortly before this book was published, I succeeded in constructing a new chronoscope, which does away with the tedious control tests described in the text (p. 180). It works for all lengths of time and with different strengths of current with the same accuracy. It is also so simple that even the unskilled may use it without previous study of the works.

The apparatus differs from the Hipp chronoscope in that a polarised magnet is used instead of an ordinary electro-magnet.

In Figs. 312 and 313, St is a steel magnet with its positive pole at N. This steel magnet is directly attached to the iron poles of the electro-magnet E. These are, therefore, permanently magnetised, and act as negative poles. The anchor of the electro-magnet E is fastened into the upper part of the steel magnet, and therefore acts as a positive pole.

Now when the anchor is pressed down towards the pole A of the electro-magnet it will be held tight. In this position the lever H, which is attached to the anchor, moves towards the left so that the pointer of the chronoscope, by means of the cross-bar as before, is disconnected from the clockwork and remains stationary.

If the lever is pushed a little towards the right, the anchor will be pulled away from the pole A and will be held tight by the pole B. For this is also a negative pole, just as A is. In this position the lever H pulls the cross-bar into the clockwork and the pointer is set in motion.

The moving of the lever from one position to the other

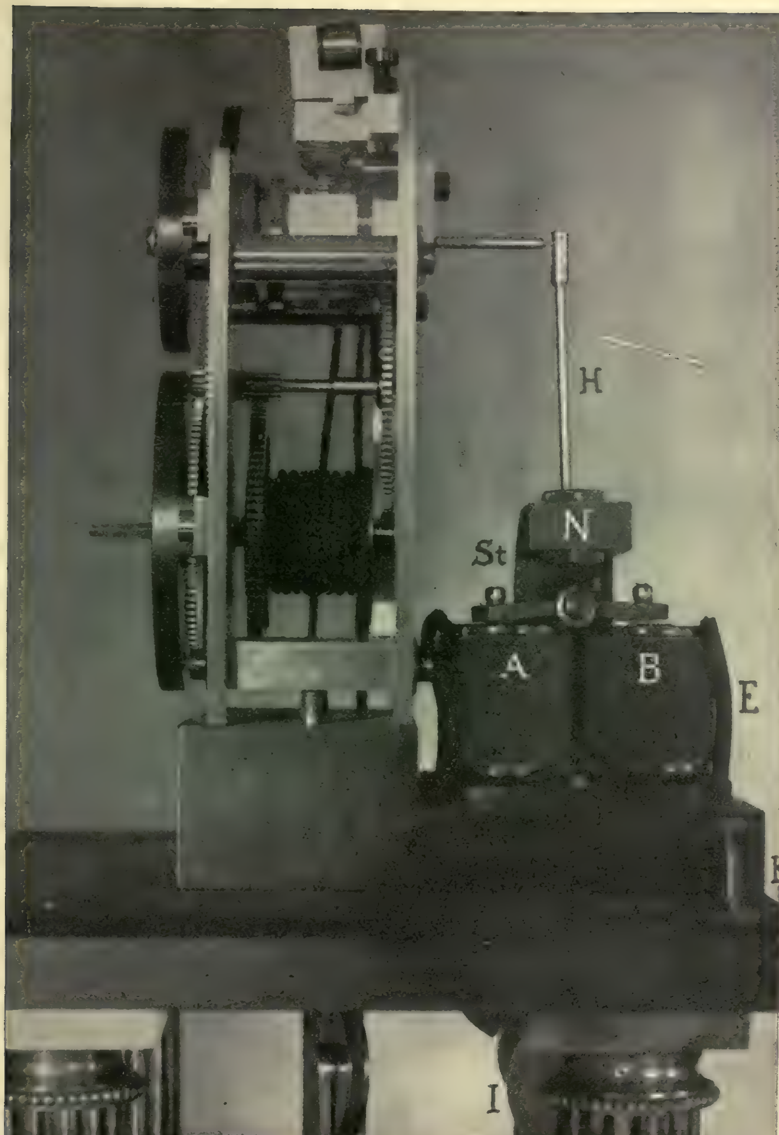


FIG. 312.—A new chronoscope.

is accomplished by means of electric shocks. The induction coil, I, is seen in Fig. 313. The terminals K and

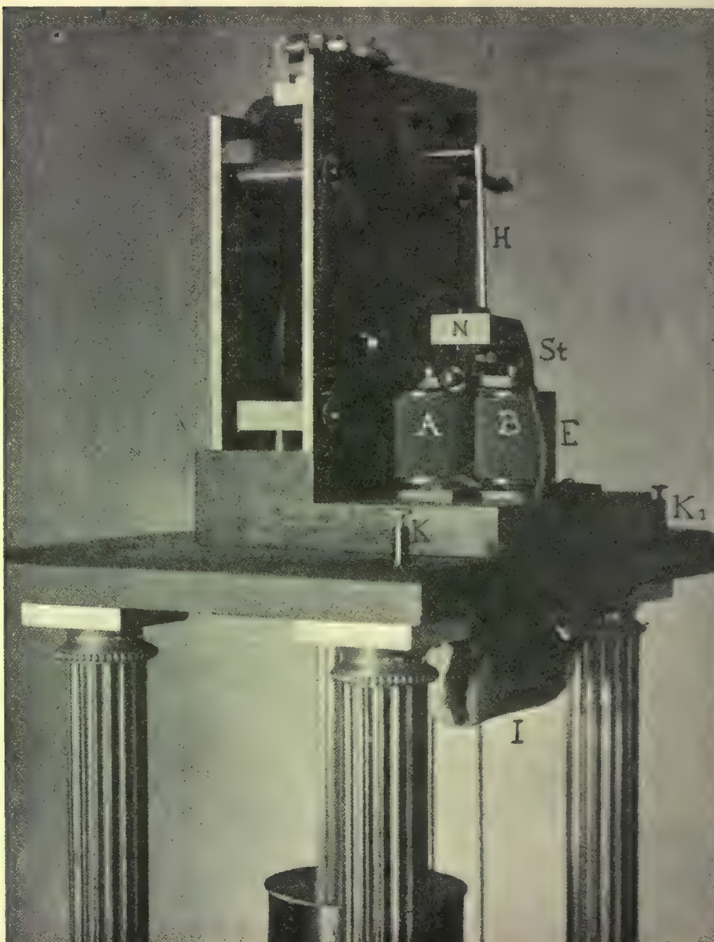


FIG. 313 —A new chronoscope.

K_1 lead to the primary coils inside, not to be seen on the picture. If an electric current is sent through these, a momentary induced current takes place in the outer secondary coil. The current can be closed by the memory

apparatus in using optical stimuli (Fig. 250), or by the sound-hammer in using acoustical stimuli (Fig. 154).

FIG. 314.—Testing the new chronoscope.

The winding of this secondary coil goes directly over into the winding of the electro-magnet E. The induced current therefore goes over into the electro-magnet, and

at the breaking of the primary current pole A becomes for a moment a positive pole, while pole B is negative. The anchor (positive pole) is therefore repulsed from A and attracted to B, and the pointer is set in motion.

When the current is broken (in reaction experiments by letting go the key), a breaking current arises in the induction coil and the electro-magnet. Since a breaking current runs in the opposite direction to a making current, B becomes a positive pole, and the anchor is repulsed and falls over to A. The pointer is disconnected from the clockwork and stands still.[1]

Since making and breaking currents are only momentary, it is absolutely immaterial to our instrument whether the reaction times are long or short. The conditions for the electro-magnet E are always the same. At making or breaking it receives a momentary current. Therefore long periods of time, such as often occur in experiments with children, are registered with the same degree of accuracy as short periods are.

Fig. 314 shows the arrangement for testing the instrument.

On the spring kymograph a simple recording magnet is attached at the top, and underneath a tuning-fork of 100 oscillations, which gets its current from the dry battery at the back.

From the two accumulators the current goes to the recording magnet, from there through the kymograph and the chronoscope and back to the accumulators.[2]

As soon as the spring of the kymograph touches the

[1] If we wish to work with make-break instead of with break-make, we must use a Pohl's commutator to reverse the primary current.

[2] It is almost better to include the recording magnet in a parallel circuit. From the positive pole of the accumulators lead two wires, one to the chronoscope and then to one terminal of the kymograph—the other wire to the recording magnet and from there to the same terminal of the kymograph. From the other terminal of the kymograph lead one wire back to the accumulators.

contact the circuit is closed. In a test for short periods of time the recorder marked 25σ (·025 sec.) and the chronoscope recorded 23σ.[1]

To test fairly long periods I led the current from the recorder through a contact key instead of through the kymograph. When the kymograph and chronoscope had been set in motion I pressed the key for various lengths of time.

This test gave the following results :—

Tuning-fork.	Chronoscope.
436σ	437σ
78	80
138	137
171	172
274	275
509	510
134	134
222	223
979	982

No adjustment of the chronoscope and no measuring of the current was necessary.

Such tests can be recommended. They are only necessary at long intervals, and are fully sufficient for our purposes.

A great advantage of the instrument is that it is impossible to send a continuous current through the electro-magnet E, even although the primary current is continuously closed. Whoever has worked with the Hipp chronoscope, knows what unpleasant consequences a permanent magnetisation of the electro-magnet has upon the accuracy of the times.

[1] It can be seen that the instrument is accurate for very short times, while the Hipp chronoscope often shows a considerable error in such cases.

APPENDIX II

LIST OF APPARATUS FOR COLLEGES OR NORMAL SCHOOLS

THE fitting up of a psychological laboratory in colleges or normal schools presents no special difficulties and is not very costly. Many experiments can be carried out in any ordinary class-room. Best of all, for the sake of convenience and cheapness, a room next to the physical laboratory is to be preferred, for in the latter many things are to be found that are necessary for our experiments, *e.g.* electric batteries, contact keys, test tubes, balances, &c.

I give below two lists. The first list would cost the sum of about £35. Compared to what is spent on physical laboratories, surely this is extremely small. If such a psychological laboratory received a further sum of £15 annually, the instruments out of the fuller list could be gradually acquired. First of all to be recommended is the chronoscope, and last of all the instruments for registering the pulse (sphygomograph, Marey tambour, a second pressure valve, and carotid capsule).

The experiments could be conducted by various small groups of students. Their results and the discussion of these would surely prove a great stimulus to the study of psychology.

1. A SHORT LIST

		£	s.	d.
Colour Mixer. Fig. 30	(about)	1	18	0
Coloured Paper	,,	0	1	6
Stimulus Hair (can be constructed). Fig. 37				
Two Dishes for lifting weights. Fig. 46 . .	,,	0	2	0

		£	s.	d.
Metal Rod for finding cold spots. Fig. 40 .	(about)	0	0	10
Spearman's Æsthesiometer. Fig. 49 . .	„	0	12	0
Metronome with mercury contacts. Fig. 58 .	„	1	18	0
Spring Kymograph.[1] Fig. 146 . . .	„	4	0	0
Kymograph. Fig. 144	„	5	10	0
Two Recording Magnets. Fig. 93 . . .	„	1	5	0
Pneumograph. Fig. 90	„	0	9	0
Marey Tambour for same with a simple lever. Fig. 82	„	1	1	6
Pressure Valve. Fig. 90	„	0	2	6
1 metre strong Rubber-tubing	„	0	1	3
6 straws for the Tambour	„	0	0	9
½ litre Fixing Solution	„	0	2	0
100 Sheets glazed paper for Kymograph . .	„	0	3	4
Electro-magnetic Tuning Fork with 100 oscillations per sec. Fig. 149	„	2	15	0
Ordinary Tachistoscope	„	2	12	0
Memory Apparatus. Fig. 213	„	6	0	0
Cover for Memory Apparatus	„	1	10	0
Paper-slips for same (500)	„	0	5	0
Dubois' Ergograph. Fig. 269	„	4	15	0
8 Weights for same	„	0	16	7
Total . .		£36	1	7

2. A Supplementary List

		£	s.	d.
New Chronoscope. Fig. 312	(about)	20	0	0
Sound-hammer. Fig. 154	„	2	15	0
Hempels' Voice-key. Fig. 234	„	3	9	0
Jaquet's Chronometer. Fig. 149	„	6	5	0
Ordinary Recorder (⅕ sec.) Fig. 147 . .	„	1	0	0
Kymograph with Stand. Fig. 145	„	10	0	0
Hair Æsthesiometer. Fig. 38	„	0	6	0
Carotid Capsule. Fig. 81 C.	„	0	3	6
Lehmann's Sphygmograph. Fig. 81 S. . .	„	0	12	6
Marey Tambour with double Lever. Fig. 82 .	„	1	5	0
1 metre strong Rubber-tubing	„	0	1	3
6 straws for Tambour	„	0	0	9
Pressure Valve. Fig. 90	„	0	2	6
Arm-rest for the Sphygmograph . . .	„	0	15	0
		£46	15	6

[1] The spring kymograph is only made by the firm W. Petzold, Leipzig. Zimmermann, Leipzig, will supply all the other instruments mentioned here.

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